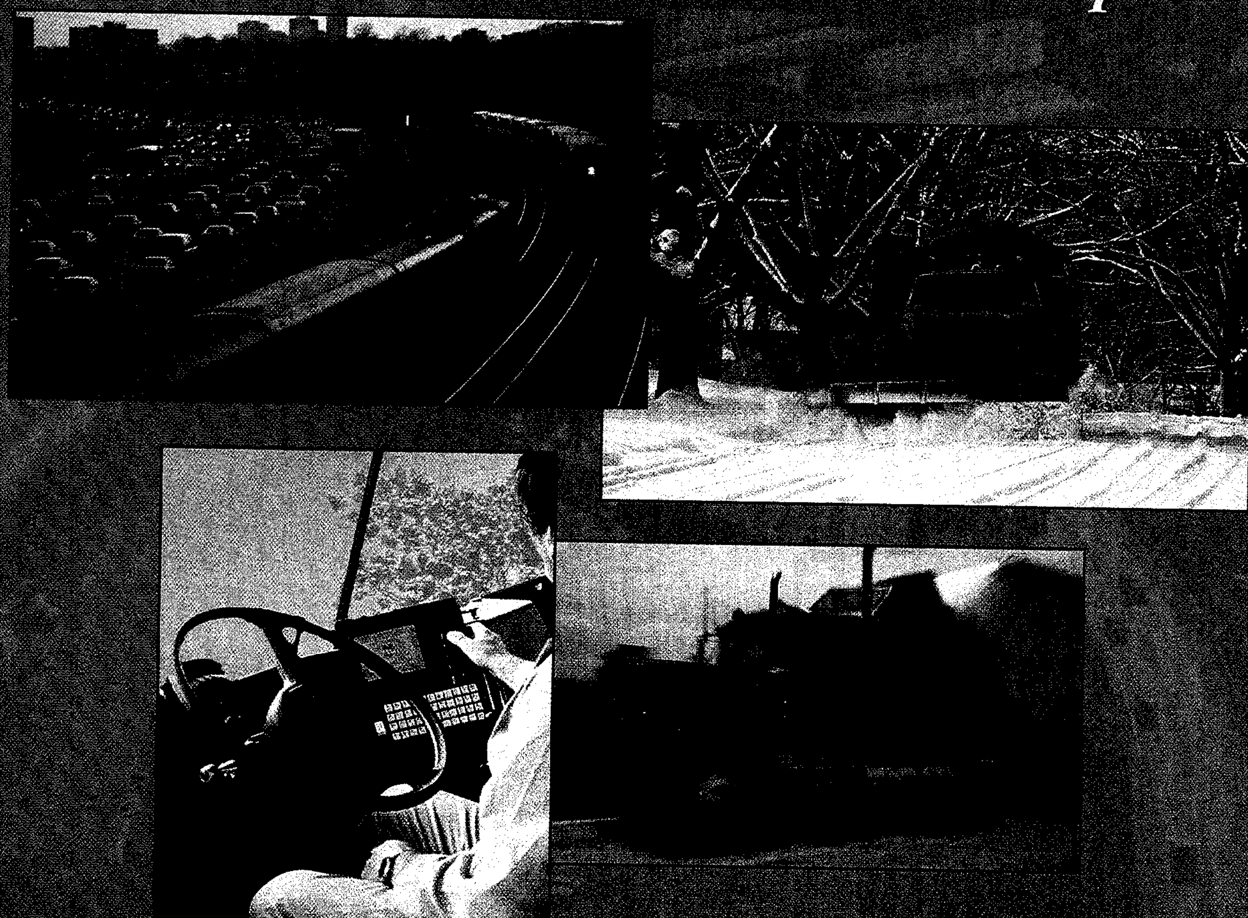
Intelligent Transportation Systems Benefits:

2001 Update



U.S. Department of Transportation
Federal Highway Administration

Intelligent Transportation Systems Benefits:

2001 Update

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16. Abstract

This report continues the series of reports that document evaluation results of ITS user services and the benefits these services provide to the surface transportation system. The organization of this report differs from that of the previous ITS Benefits reports. While previous reports were cumulative, this report only summarizes major findings of data included in previous reports in the series. More detailed discussion is included for data collected since the 1999 report. Referenced data are classified into a structure that reflects individual ITS program areas. These program areas include metropolitan and rural infrastructure, ITS for Commercial Vehicle Operations (ITS/CVO), and Intelligent Vehicle user services. Data within the report reflect empirical results from field operations of deployed systems, supplemented with benefits information based upon modeling studies and statistical studies.

This is a reference report. It provides a snapshot of the information contained in the ITS Benefits Database (www.benefitcost.its.dot.gov), as of February 15, 2001. The online database is updated more frequently and provides more detail on specific references than this report. Both the report and database highlight benefits identified by other authors and refer the reader to information sources. The interested reader is encouraged to obtain source documents in order to appreciate the assumptions and constraints placed upon interpretation of results. It is the intent of the ITS Joint Program Office to update this report periodically.

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LISTING OF TABLES

LISTING OF FIGURES

EXECUTIVE SUMMARY

Since December of 1994, the United States Department of Transportation's (U.S. DOT's) ITS Joint Program Office (JPO) has been actively collecting information on the impacts that ITS and related projects have on the operation and management of the nation's surface transportation system. The evaluation of ITS is an ongoing process. Significant knowledge is available for many ITS services, but gaps in knowledge also exist.

The purpose of this report is to provide a summary of data available in the ITS Benefits Database. It is a compendium of reported impacts of ITS that have been collected from a number of sources, and builds upon a history of similar summary reports that have been authored over the last six years. Intended to be a reference report, this report highlights benefits identified by other authors. The purpose of this report is to provide the JPO with an additional tool to transmit existing knowledge of ITS benefits to the transportation professional who may not be well versed in ITS products and services. This report can also provide the research community with information about where further analysis is required in the ITS program. It demonstrates that in general all ITS services have shown some positive benefit and that negative impacts are usually outweighed by other positive results. For example, higher speeds and improved traffic flow result in increases in Nitrous Oxides, while other measures which indicate increased emissions, such as fuel consumption, travel time, and delay, are reduced.

General conclusions and results are developed throughout the body of the report. Due to the nature of the data, it is often difficult to compare data from one project to another. This is because of the differences in context or conditions between different ITS implementations. Thus, statistical analysis of the data is not done across data points. In several cases, ranges of reported impacts are presented and general trends can be discussed. These cases include traffic signal systems, automated enforcement, ramp metering, and incident management.

As indicated in Table ES-1, most of the data collected to date are concentrated within metropolitan areas. The heaviest concentrations of data in the metropolitan area are in arterial management systems, freeway management, incident management, transit management, and regional multimodal traveler information. Most of the available data on traffic signal control systems are from adaptive traffic control. For freeway management, most data are concentrated around benefits related to ramp metering. There are also now several studies on the benefits of ITS at highway rail intersections, which differs from the 1999 report when no evaluations were available.

Number of References

0 - ○
1 to 3 - ◔
4 to 6 - ◑
7 to 10 - ◕
>10 - ●

		Safety	Time & Delay	Capacity/Throughput	Cost	Customer Satisfaction	Energy & Environment	Other
Metropolitan	Arterial Management Systems	●	●	◔	◕	◑	◕	○
	Freeway Management	●	●	◑	◑	◑	◑	○
	Transit Management	◑	●	◔	◕	◑	◔	○
	Incident Management	◑	●	◔	●	◑	◑	○
	Emergency Management	◑	◔	○	○	○	○	○
	Electronic Toll Collection	◔	◔	◔	◔	◔	◔	○
	Electronic Fare Payment	○	◔	○	◔	◔	○	◔
	Highway-Rail Intersection	◔	◔	○	○	◔	◔	○
	Regional Mutimodal Travel Information	◑	◑	◔	◔	◕	◑	◔
	Information Management	○	○	○	○	○	○	○
Rural	Traveler Safety and Security	◔	○	○	○	◔	○	○
	Emergency Services	◔	◔	○	◔	○	○	○
	Tourism and Travel Information	○	○	○	○	○	○	○
	Public Transit and Mobility Services	○	○	○	◔	○	○	○
	Infrastructure Operation and Maintenance	◔	◔	○	○	○	○	○
	Road Weather Management	◑	◑	◔	◑	○	○	○
ITS/CVO	Safety Assurance	○	○	○	◑	◔	○	○
	Credentials Administration	○	○	○	◔	◔	○	◔
	Electronic Screening	◔	◔	○	◑	◔	○	○
	Carrier Operations	○	◔	○	◑	◔	◔	◑
I.V.	Driver Assistance	◔	◑	◔	○	◔	○	○
	Platform Specific	○	○	○	○	○	○	○

Table ES-1: Summary of Available Data by Benefit Measure (as of 15 February 2001)

In past reports, rural applications have had few data points, but an increase in the implementation and evaluation of rural ITS has changed this. Several state and national parks are now examining and implementing improved tourism and travel information systems and several rural areas are implementing public travel services. Also, many states are now examining the benefits of incorporating ITS, specifically weather information, into the operation and maintenance of facilities and equipment. Much of the data reported for rural ITS are concentrated in the areas of crash prevention and security. Also, a significant amount of information is available for road weather management activities, including winter weather-related maintenance, pavement condition monitoring, and dissemination of road weather information.

ITS for Commercial Vehicle Operations (ITS/CVO) continues to provide benefits to both carriers and state agencies. ITS/CVO program areas usually report benefits data from directly measurable effects. Therefore, it might be expected that these data are accurate and only a few data points would be necessary to convince carriers, states, and local authorities of the possible benefits of implementing these systems. To date, most of the data collected for ITS/CVO are for cost, travel time, and delay savings for carrier operations.

ITS program areas and user services associated with driver assistance and specific vehicle classes are still being developed and planned. Although a few of these services are available in the marketplace, much of the data currently associated with these services are predicted or projected based on how systems are expected to perform. As market penetrations increase and improved systems are developed, there will be ample opportunity to measure and report data based on actual measurements.

The Benefits Database Desk Reference, Table ES-2 on the following page, also provides a brief summary of the metropolitan data available in the online database. The desk reference is updated regularly and is also available at the database website.

Given the continued investment in ITS that is occurring at the national, state, and local levels, there will continue to be opportunities to measure and report more data on the impacts of ITS. As these data become available, it may be possible to perform more detailed analyses for particular program areas or benefits measures, for example, through the use of meta-analysis techniques. These analyses are expected to assist in improving the estimated ranges of impact, and the level of confidence in those ranges.

Metropolitan Benefits By Program Area

Program Area	Benefit Measure	Summary
Arterial Management Systems	Safety Improvements	Automated enforcement of traffic signals has reduced violations 20% to 75%
	Delay Savings	Adaptive Signal Control has reduced delay from 14% to 44%
	Throughput	
	Customer Satisfaction	72% of surveyed drivers felt "better off" after signal control improvements in Michigan
	Cost Savings	Transit Signal Priority on Toronto transit line allowed same service with one less vehicle
	Environmental	Improvements to traffic signal control have reduced fuel consumption 2% to 13%
	Other	Adaptive Control has reduced stops from 10% to 41%
Freeway Management Systems	Safety Improvements	Ramp Metering has shown 15% to 50% reduction in crashes
	Delay Savings	11 to 93.1 vehicle hours reduced due to ramp metering I-494: Minneapolis
	Throughput	Systemwide study in Minneapolis - St. Paul found 16.3% increase in throughput
	Customer Satisfaction	After Twin Cities shutdown, 69% of surveyed travelers support modified continued operation
	Cost Savings	Georgia Navigator $44.6 million/year in incident delay reduction (integrated system)
	Environmental	
	Other	Ramp Metering has shown 8% to 60% increases in speed on freeways
Transit Management Systems	Safety Improvements	AVL with silent alarm supported 33% reduction in passenger assaults on Denver System
	Delay Savings	Reported improvements in on-time performance from 9% to 23% with CAD/AVL
	Throughput	
	Customer Satisfaction	Customer complaints decreased 26% after Denver installed CAD/AVL
	Cost Savings	AVL reduced San Jose paratransit expenses from $4.88 to $3.72 per passenger
	Environmental	
	Other	Reductions in fleet size from 4% to 9% due to more efficient bus utilization
Incident Management Systems	Safety Improvements	San Antonio, TX reports reduced crash rate of 41%
	Delay Savings	Reductions range from 95 thousand to 2 million hours per year
	Throughput	
	Customer Satisfaction	Customers very satisfied with service patrols (hundreds of letters)
	Cost Savings	Cost Savings from $1 to $45 million per year, varying with extent of system
	Environmental	TransGuide reduced fuel consumption up to 2600 gal/major incident
	Other	
Emergency Management Systems	Safety Improvements	
	Delay Savings	
	Throughput	
	Customer Satisfaction	95% of drivers equipped with PushMe Mayday system felt more secure
	Cost Savings	
	Environmental	
	Other	
Electronic Toll Collection	Safety Improvements	Carquinez Bridge, CA: Increase in crashes (27 to 30) and Injuries between 1996 and 1997*
	Delay Savings	Carquinez Bridge, CA: person time savings of 79,919 hours (per year) or about $1.07 million
	Throughput	Tappan Zee Bridge: Manual lane 400-450 vph, ETC lane 1000 vph
	Customer Satisfaction	
	Cost Savings	Roadway Maintenance can be reduced 14%
	Environmental	Florida: Reduced CO 7.3%, HC 7.2%, Increased NO_x 34% with 40% ETC usage
	Other	Value pricing using ETC in Florida resulted in 20% of travelers adjusting departure time
Electronic Fare Payment	Safety Improvements	
	Delay Savings	
	Throughput	
	Customer Satisfaction	In Europe, 71% to 87% user acceptance of coordinated smart cards for transit/city services
	Cost Savings	New Jersey Transit estimates $2.7 million cash handling reduction annually
	Environmental	
	Other	
Highway-Rail Intersections	Safety Improvements	92% of train engineers felt safety equal or greater with automated horn warning system
	Delay Savings	
	Throughput	
	Customer Satisfaction	School bus drivers felt in-vehicle warning devices enhanced awareness of crossings
	Cost Savings	
	Environmental	Automated horn warning system reduced noise impact area by 97%
	Other	
Regional Multimodal Traveler Information	Safety Improvements	Crash rate for drivers using web traveler information in San Antonio reduced 0.5%
	Delay Savings	San Antonio modeling results indicate a 5.4% reduction in delay for web site users
	Throughput	
	Customer Satisfaction	38% of TravTek Users found in-vehicle navigation useful in unfamiliar areas
	Cost Savings	ROUTES (London): estimated 1.3 million pounds sterling due to increased transit ridership
	Environmental	SmartTraveler Boston: estimated reductions NO_x 1.5%, CO 33%
	Other	

Source: www.benefitcost.its.dot.gov *Database also includes negative impacts of ITS. Date: 3/14/2001

Table ES-2: Benefits Database Desk Reference

1.0 INTRODUCTION

Americans drive more than 2.6 trillion miles a year on our nation's roadways. Transit ridership reached nine billion trips in 1999, the highest level in 40 years. The increasing demand for transportation caused by our expanding economy is causing the transportation system to reach the limits of its existing capacity. Intelligent Transportation Systems (ITS) can help ease this strain through the application of modern information technology and communications.

The goal of ITS is to improve the transportation system to make it more effective, more efficient, and safer. Building new transportation infrastructure is expensive and environmentally risky. In most urban areas where more capacity is needed, it is becoming physically impossible to build enough new roads or new lanes to meet transportation demand. By applying the latest technological advancements to our transportation system, ITS can help meet increasing demand for transportation by improving the quality, safety, and effective capacity of our existing infrastructure.

ITS represents a wide collection of applications, from advanced signal control systems to ramp meters to collision warning systems. In order to apply ITS technologies most effectively, it is important to know which technologies are most effectively addressing the issues of congestion and safety. Some technologies provide more cost-effective benefits than others, and as technology evolves, the choices to deployers change. Often, several technologies are combined in a single integrated system, providing synergistic benefits that exceed the benefits of any single technology. It is important to know which technologies and technology combinations provide the greatest benefits, so that transportation investments can be applied most effectively to meet the growing transportation demands of our expanding economy.[1]

1.1 GOALS OF THE ITS BENEFITS REPORT AND DATABASE

1.1.1 The ITS Benefits Database

To expand the understanding of ITS benefits, the United States Department of Transportation's (U.S. DOT's) ITS Joint Program Office (JPO) has been actively collecting information regarding the impact of ITS implementations. In support of this effort, the JPO sponsored the development of the National ITS Benefits Database. The database is available to the public at www.benefitcost.its.dot.gov. The database contains the most recent data collected by the JPO. Its purpose is to provide the JPO with a tool to transmit existing knowledge of ITS benefits to the transportation professional who may not be well versed in ITS products and services. The database also provides the research community with information on ITS areas where further analysis may be required.

The Benefits Database website contains detailed summaries of each of the ITS evaluation reports reviewed by the JPO. Summaries on the web pages provide additional background on the context of the evaluations, the evaluation methodologies used, and links to the source documentation, if available online. While the JPO publishes reports such as this periodically, the online database is updated quarterly to reflect the most recent reports reviewed. The online database also provides several capabilities to simplify access to information relevant to a researcher's purpose. In addition to using the classification system in this report, interested researchers can access document summaries classified by the location of the implementation, the performance measures reported for the projects, or

[1] *The Changing Face of Transportation.* U.S. Dept. of Transportation, Bureau of Transportation Statistics (BTS00-007). 2000.

relevant keywords. These capabilities of the online database simplify access to the most recently available data on ITS benefits identified by the JPO. The website also contains a discussion of the criteria and sources used to determine whether or not a report should be added to the ITS Benefits Database.

1.1.2 Purpose of this Report

This periodically updated report is a compendium of reported impacts of ITS that have been collected from a number of sources. Its purpose is to provide a summary of data available in the ITS Benefits Database. The report builds upon a history of similar summary reports that have been authored over the last six years. The last report, titled *ITS Benefits: 1999 Update*,[2] was published in May of 1999. For this June 2001 report, a concentrated effort was made to include and highlight recent data. However, this report also references and contains data included in previous versions. Older data points are primarily used to develop general conclusions about the impacts of ITS services and are not described in as much detail as the more recent data. This report is intended to be a reference report; it highlights benefits identified by other authors. The interested reader is encouraged to obtain source information to appreciate the assumptions and constraints placed upon interpretation of results.

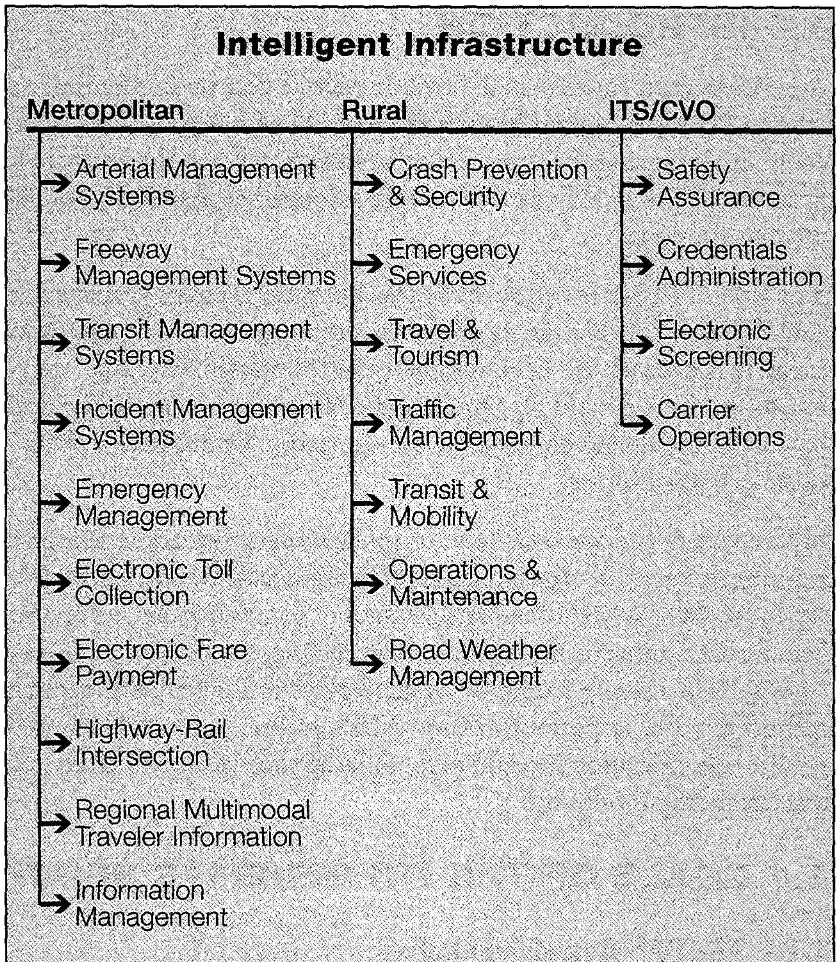


Figure 1-0: Intelligent Infrastructure Taxonomy for Reporting ITS Benefits

1.2 ORGANIZATION OF THIS REPORT

This report follows a taxonomy for reporting ITS benefits data. The ITS taxonomy used in this report groups benefits data into two major components: Intelligent Infrastructure and Intelligent Vehicles. These components are then divided into program areas and specific ITS application areas. While this taxonomy was not intended to reflect the official structure of the ITS program, it has proven useful in promoting discussion within the ITS community and has been used to demonstrate the breadth of the ITS program. An overview of this taxonomy is represented in Figures 1-0 and 1-1. A more detailed version of the taxonomy is available at the ITS Benefits Database website cited in the header of pages within this document.

[2] Proper, Allen T. *Intelligent Transportation Systems Benefits: 1999 Update.* U.S. Department of Transportation, ITS Joint Program Office (FHWA-OP-99-012). May 1999.

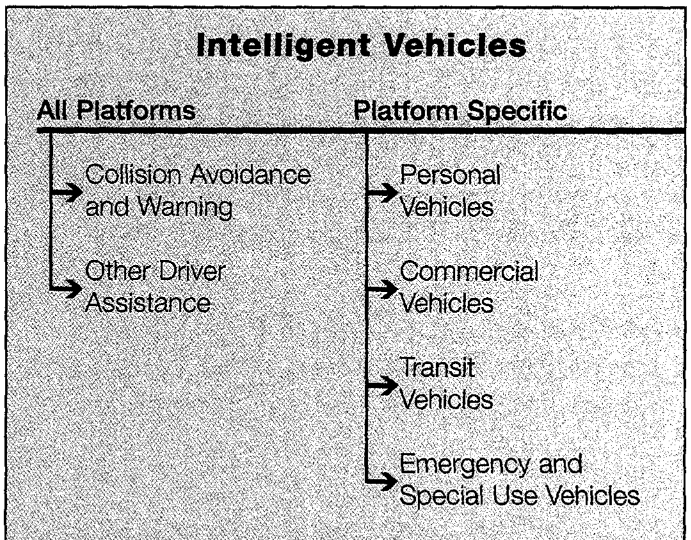


Figure 1-1: Intelligent Vehicles Taxonomy for Reporting ITS Benefits

It is realized that the taxonomy cannot represent all aspects of ITS. For example, many of the program areas can be dependent on or heavily influenced by other areas. This dependency is not well shown in the taxonomy. It is also understood that many ITS program areas share information and operate in a cooperative manner which is difficult to capture in this form. For example, incident management systems can directly influence emergency response by providing timely and accurate information on incident location and severity. Additionally, in-vehicle systems, such as route guidance, require a cooperative infrastructure that can provide routing and/or travel time information to vehicle systems.

It is also known that the taxonomy for classification of data by geographic setting (i.e., metropolitan, rural) may not be best suited for some data. For example, tourist information is generally classified in rural ITS infrastructure. However, most metropolitan areas also have tourism concerns. Therefore, this classification of data does not imply that systems are not implemented in or do not impact other geographic settings. In this report, data are classified by those settings most often associated with the current deployment of the ITS program area or service.

Classification of ITS benefits was based on the geographic setting (e.g., metropolitan) or functionality (e.g., ITS/CVO) of the ITS services referenced in the source documentation. This report attempts to account for the influences and cooperative aspects of ITS. In the case of integrated deployments, data are classified in this report under the program area that the implementation most directly supports. In some cases, source documents did not provide enough detailed information to classify referenced data. When this occurred, the authors made a judgment to determine how these data should be classified.

Sections within chapters of this report discuss each program area for which benefit data are available. Each section begins with a brief description of the ITS application and the current state of knowledge. Following this are overviews of all data and general conclusions that can be made about the ITS application. Finally, recent data, including what the authors consider to be the most important or interesting results collected since the 1999 report, are discussed.

1.3 A FEW GOOD MEASURES

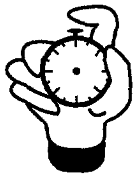
In the spring of 1996, the ITS Joint Program Office (JPO) established a set of ITS Program goal areas directly related to the ITS strategic plan.[3] The goal areas include improving traveler safety, improving traveler mobility, improving system efficiency, increasing the productivity of transportation providers and conserving energy while protecting the environment. The JPO also identified several measures of effectiveness to evaluate the performance of ITS services in each goal area. The measures are known as the "Few Good Measures" and are intended to enable project managers to gauge the effects and impacts of ITS.

The remainder of this section is an overview of the various measures of effectiveness within each goal area. Throughout the document, icons are placed next to each summary to reflect the measures reported. Benefits that are not included in the set of measures are also included in the report, without using icons to reference them.

SAFETY

An explicit objective of the transportation system is to provide a safe environment for travel while continuing to strive to improve the performance of the system. Although undesirable, crashes and fatalities are inevitable occurrences. Several ITS services aim to minimize the risk of crash occurrence. This goal area focuses on reducing the number of crashes, and lessening the probability of a fatality should a crash occur. Typical measures of effectiveness used to quantify safety performance include the overall crash rate, fatality crash rate, and injury crash rate.

ITS services should also strive to reduce the crash rate of a facility or system. Crash rates are typically calculated in terms of crashes per year or crashes per million vehicle miles of travel.



MOBILITY

Improving mobility by reducing delay and travel time is a major goal of many ITS components. To highlight this goal, in 1996 the Secretary of Transportation launched a new metropolitan ITS integration initiative, "Operation TimeSaver." Measures of effectiveness typically used to evaluate the performance of such goal-oriented projects include the amount of delay or the variability in travel time.

Delay can be measured in many different ways, depending on the type of transportation system being analyzed. Delay of a system is typically measured in seconds or minutes of delay per vehicle. Also, delay for users of the system may be measured in person-hours. Delay for freight shipments could be measured in time past scheduled arrival time of the shipment. Delay can also be measured by observing the number of stops experienced by drivers before and after a project is deployed or implemented.

Travel time variability indicates the variability in overall travel time from an origin to a destination in the system, including any modal transfers or en-route stops. This measure of effectiveness can readily be applied to intermodal freight (goods) movement as well as personal travel. Reducing the variability of travel time improves the reliability of arrival time estimates that travelers or companies use to make planning and scheduling decisions. By improving operations, improving incident response, and providing information on delays, ITS services can reduce the variability of travel time in transportation networks. For example, traveler information products can be used in trip planning to help re-route commercial drivers around congested areas resulting in less variability in travel time.

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[3] *Strategic Plan for Intelligent Vehicle Highway Systems in the United States.* ITS America Report (IVHS-Amer-92-3). Washington, DC: May 20, 1992.

EFFICIENCY

Many ITS components seek to optimize the efficiency of existing facilities and use of rights-of-way so that mobility and commerce needs can be met while reducing the need to construct or expand facilities. This is accomplished by increasing the effective capacity of the transportation system. Effective capacity is the "maximum potential rate at which persons or vehicles may traverse a link, node, or network under a representative composite of roadway conditions," including "weather, incidents, and variation in traffic demand patterns."[4] Capacity, as defined by the *Highway Capacity Manual*, is the "maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a given point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions."[5] The major difference between effective capacity and capacity is that capacity is generally measured under typical conditions for the facility, such as good weather and pavement conditions, with no incidents affecting the system, while effective capacity can vary depending upon these conditions and the use of management and operational strategies. Throughput is defined as the number of persons, goods, or vehicles traversing a roadway section or network per unit time. Increases in throughput are sometimes realizations of increases in effective capacity. Under certain conditions, it may reflect the maximum number of travelers that can be accommodated by a transportation system. Throughput is more easily measured than effective capacity and therefore can be used as a surrogate measure when analyzing the performance of an ITS project.

PRODUCTIVITY

ITS implementation frequently reduces operating costs and allows productivity improvements. In addition, ITS alternatives may have lower acquisition costs and life cycle costs compared to traditional transportation improvement techniques. The measure of effectiveness for this goal area is cost savings as a result of implementing ITS. Another way to view the cost savings is to quantify the cost savings between traditional and ITS solutions to addressing problems.

ENERGY AND ENVIRONMENT

The air quality and energy impacts of ITS services are very important considerations, particularly for non-attainment areas. In most cases, environmental benefits can only be estimated by the use of analysis and simulation. The problems related to regional measurement include the small impact of individual projects and large numbers of exogenous variables including weather, contributions from non-mobile sources or other regions, and the time-evolving nature of ozone pollution. Small-scale studies generally show positive impacts on the environment. These impacts result from smoother and more efficient flows in the transportation system. However, environmental impacts of travelers reacting to large-scale deployment in the long term are not well understood.

Decreases in emission levels and energy consumption have been identified as measures of effectiveness for this goal area. Specific measures of effectiveness for emission levels and fuel use include:

- Emission levels (CO, NO_X and HC) (kg or tons of pollutant)
- Fuel use (liters or gallons)
- Fuel economy (km/L or miles/gal)

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[4] McGurrin, Michael and Karl Wunderlich. "Running at Capacity." *Traffic Technology International.* April/May 1999.

[5] *Highway Capacity Manual 2000.* Transportation Research Board, National Research Council. Washington, DC: 2000.

CUSTOMER SATISFACTION

Given that many ITS projects and programs were specifically developed to serve the public, it is important to ensure that user (i.e., customer) expectations are being met or surpassed. Customer satisfaction measures and characterizes the distance between users' expectations and experiences in relation to a service or product. The central question in a customer satisfaction evaluation is, "Does the product deliver sufficient value (or benefits) in exchange for the customer's investment, whether the investment is measured in money or time?" Typical results reported in evaluating the impacts of customer satisfaction with a product or service include product awareness, expectations of product benefit(s), product use, response (decision-making or behavior change), realization of benefits, and assessment of value. Although satisfaction is difficult to measure directly, measures related to satisfaction can be observed including amount of travel in various modes, mode choices, and the quality of service as well as the volume of complaints and/or compliments received by the service provider.

In addition to user or customer satisfaction, it is necessary to evaluate the satisfaction of the transportation system provider or manager. For example, many ITS projects are implemented to better coordinate between various stakeholders in the transportation arena. In such projects, it is important to measure the satisfaction of the transportation provider to ensure the best use of limited funding. One way to measure the performance of such a project is to survey transportation providers before and after a project was implemented to see if coordination was improved. It may also be possible to bring together providers from each of the stakeholder groups to evaluate their satisfaction with the system before and after the implementation of an ITS project.

1.4 IMPACTS OF ITS

This report includes both the positive and negative reported impacts of ITS implementations. The majority of available references demonstrate positive benefits. This is true both for actual deployments and for analytical studies predicting future benefits. The number of cases reporting negative results is fairly small. It is also recognized that negative impacts may be under-reported in the literature.

2.0 BENEFITS OF METROPOLITAN ITS INFRASTRUCTURE

Metropolitan ITS consist of those program areas that are primarily implemented in urban and suburban geographic locations. This does not imply that these systems are not implemented in or do not impact other geographic settings. However, they are more often associated with urban areas.

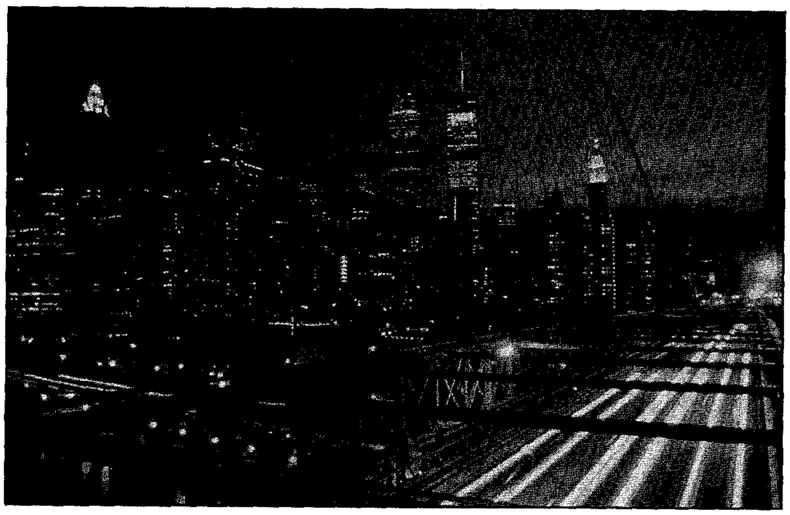
The metropolitan ITS infrastructure is classified into 10 major components. These components are summarized in Figure 2-0, below.

Metropolitan

- Arterial Management Systems
- Freeway Management Systems
- Transit Management Systems
- Incident Management Systems
- Emergency Management
- Electronic Toll Collection
- Electronic Fare Payment
- Highway-Rail Intersection
- Regional Multimodal Traveler Information
- Information Management

Figure 2-0: Metropolitan ITS Components

Several metropolitan areas are implementing ITS services that are very highly integrated. Integration is accomplished by creating a number of interfaces or "links" between components, systems, services, or program areas. These links are used to share operational information and allow for sharing of infrastructure. Figure 2-1 demonstrates a set of metropolitan integration links. A number is used to refer to the specific linkage made between each program area. For example, link number two represents the sharing of arterial traffic condition information originating from a traffic signal system with a freeway management system. To highlight the impact of the interaction between services on system benefits, data regarding integrated systems are highlighted in this chapter by icons with a connecting line that depicts the flow of information between systems. The example in Figure 2-2 represents integration between arterial management and incident management systems.



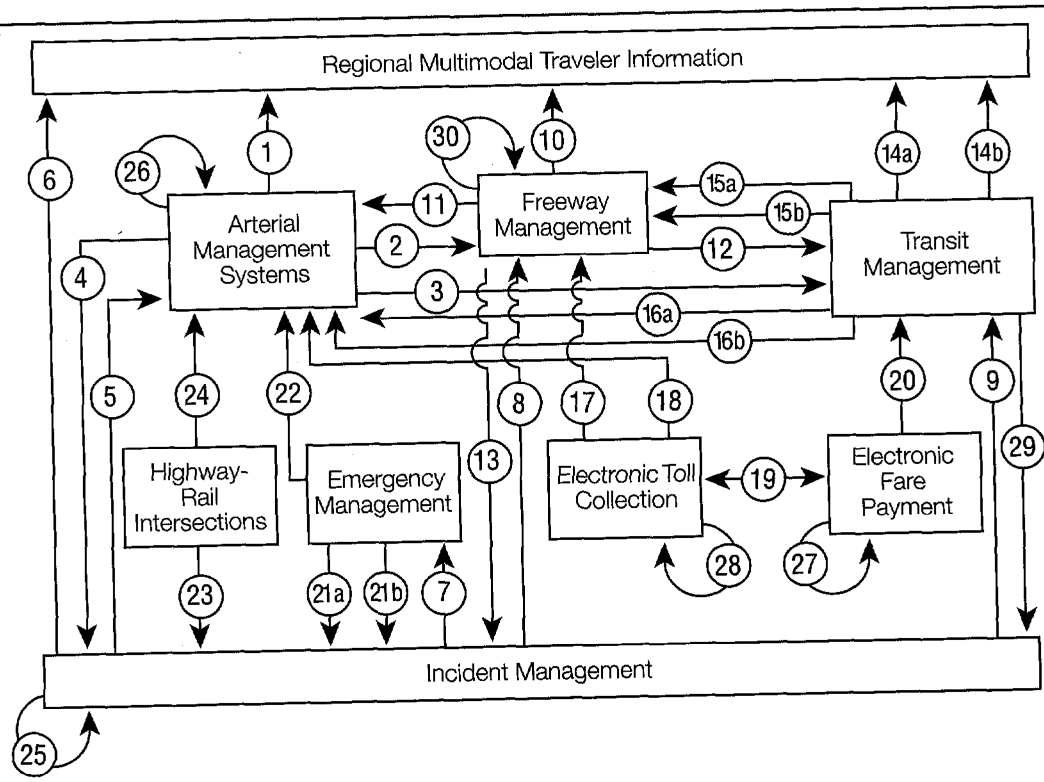


Figure 2-1: Integration of Metropolitan ITS Components

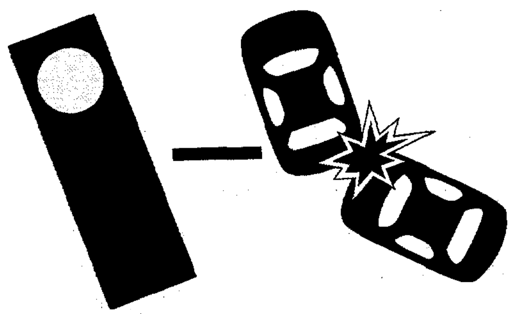
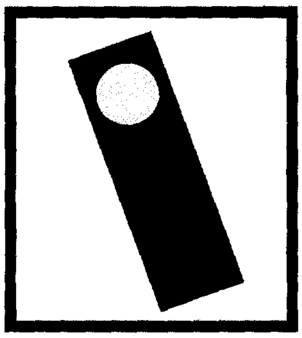


Figure 2-2: Arterial to Incident Management Integration Icon

For a more complete understanding of these components and how they are integrated, the reader is referred to the following documents:

- *Tracking the Deployment of Integrated Metropolitan Intelligent Transportation Systems Infrastructure in the USA: FY99 Results.* FHWA Report (FHWA-OP-00-016). March 2000. Electronic Document Number 13159.
- "Measuring ITS Deployment and Integration." Prepared for the FHWA ITS JPO. January 1999. Electronic Document Number 4372.

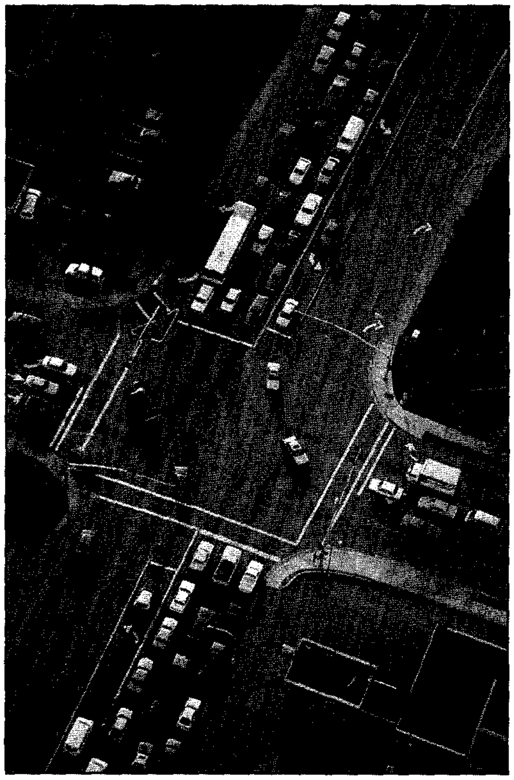
Both documents are electronically available on the FHWA electronic document library at www.its.dot.gov/itsweb/welcome.htm. The JPO-sponsored deployment tracking website, www.itsdeployment.its.dot.gov, contains updated information on ITS deployment in the United States. Results of the FY 2000 surveys are expected to be available at the deployment tracking website by Summer 2001.



2.1 ARTERIAL MANAGEMENT SYSTEMS

Arterial management systems are used to manage traffic by employing various detection and control devices along arterial roadways. Included in this program area are arterial traffic management systems that provide surveillance and traffic signal control, and some systems that provide travelers with audio or visual information on arterial roadway travel conditions.

Traffic signal control systems are upgraded for a number of reasons, primarily to improve traffic flow and simplify system maintenance. Adaptive control systems coordinate control of traffic signals across metropolitan areas, adjusting the lengths of signal phases based on prevailing traffic conditions. Information collected by detectors associated with arterial management systems may be shared between jurisdictional boundaries and with other components of metropolitan ITS infrastructure. Many jurisdictions have implemented traffic signal control systems that provide signal priority and preemption for transit and emergency vehicles, respectively. Arterial management systems may also include automated enforcement programs that increase compliance with speed limits and traffic signals. Figure 2-3 shows the format for the classification of benefits used in the taxonomy for arterial management systems.



For a summary of arterial management systems deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

Arterial Management Systems

- → Traffic Surveillance
- → Traffic Control
  - → Adaptive Signals
  - → Signal Priority
    - → Transit
    - → Emergency
  - → Pedestrian Control
- → Information Display
  - → Dynamic Message Signs
  - → Highway Advisory Radio
  - → In-Vehicle Signing
- → Public Safety
  - → Enforcement

Figure 2-3: Taxonomy for Arterial Management System Benefits

2.1.1 Summary of Arterial Management System Impacts

Based on the results of published evaluations, it appears that advanced traffic signal control systems, such as those providing adaptive control, provide a significant positive benefit. However, it is difficult to generalize an expected benefit for these services. Benefits for an individual area depend on a number of operational variables that are unique to each implementation. Variables may include the number of intersections or signals in a corridor, spacing of intersections, size of study area, corridor lengths, vehicle demand patterns, etc. It is possible to make some general conclusions based on reported results that should be useful to decision-makers.

Figure 2-4 presents the measured values for percent reduction in the number of stops due to improved traffic signal control as detailed in previous reports and in the following section of this report. Studies evaluated systems implemented in Toronto, Canada;[6] Paris, France;[7] Oakland County, Michigan;[8] Los Angeles, California;[9] and Madrid, Spain.[10] Many of the cited studies evaluated the performance of adaptive control systems, while others investigated the impact of systems automating the selection of signal timing plans appropriate for particular time periods. As one would expect, if the flow of green bands in a corridor can be maintained as traffic patterns change, the number of stops can be reduced. The reported benefit of these systems ranges from a 10% to 41% reduction in stops; however, the small number of evaluations precludes statistical analysis of the results. Larger benefits are achieved when comparing improved signal control systems to systems using previously fixed timing plans in study corridors where significant variations in traffic patterns exist.

Figures 2-5 and 2-6 provide an overview of the impact of improved traffic signal operations on travel time and delay. The charts are based on evaluations of implemented systems discussed in the following section, as well as several discussed in previous ITS Benefits reports.[11, 12, 13, 14, 15, 16, 17, 18] As expected, the reductions in travel time are far less than those reported for delay avoided. Furthermore, there is an apparent large range of possible values for each measure. A likely contributing factor to this range is that individual studies may define or measure travel time and delay differently. Travel time may be defined as the time required for an entire trip or the time needed to traverse a corridor or fraction of the trip. Delay may be defined as stopped time due to signals only or as the time exceeding a predetermined base travel time. Depending on the definitions used, and other operational conditions, estimated changes in travel time range from a 6% increase in travel time and 20% decrease. Likewise, reductions in delay due to adaptive control may range between 14% and 44%.

Reports evaluating the impacts of arterial management systems on energy consumption and the environment indicate that the impacts are generally positive, though relatively minor. Figure 2-7 depicts the impact of improved traffic signal control on fuel consumption, as described in evaluations of systems in Phoenix, Arizona;[19] Paris, France;[20] Toronto, Canada;[21] and Los Angeles, California.[22] A few reports discuss the impacts of arterial management systems on motor vehicle emissions. The impact appears to be positive, with the exception of

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6 Siemens Automotive, USA. "SCOOT in Toronto." *Traffic Technology International.* Spring 1995.

7 Beteille, J. and Briet, G. "Making Waves in Traffic Control." *Traffic Technology International.* Annual Review, 1997.

8 Barbaresso, James C. *Preliminary Findings and Lessons Learned From The Fast-Trac IVHS Program.* Road Commission for Oakland County. Beverly Hills, MI, 1994.

9 City of Los Angeles Department of Transportation. *Automated Traffic Surveillance and Control (ATSAC) Evaluation Study.* June 1994.

10 Peck, C., M. Blanco and J. Lopez. "Learning from the User: Next Steps for ITACA's Adaptive Control." *Traffic Technology International.* Annual Review, 1999. p. 155-158

11 Zhou, Wei-Wu, *et al.* "Fuzzy Flows." *ITS: Intelligent Transportation Systems.* May/June 1997.

12 Beteille, *et al.* 1997.

13 Siemens Automotive 1995.

14 Glassco, R, *et al. Studies of Potential Intelligent Transportation System Benefits Using Traffic Simulation Modeling.* Mitretek Systems Report (MP96W0000101). June 1996.

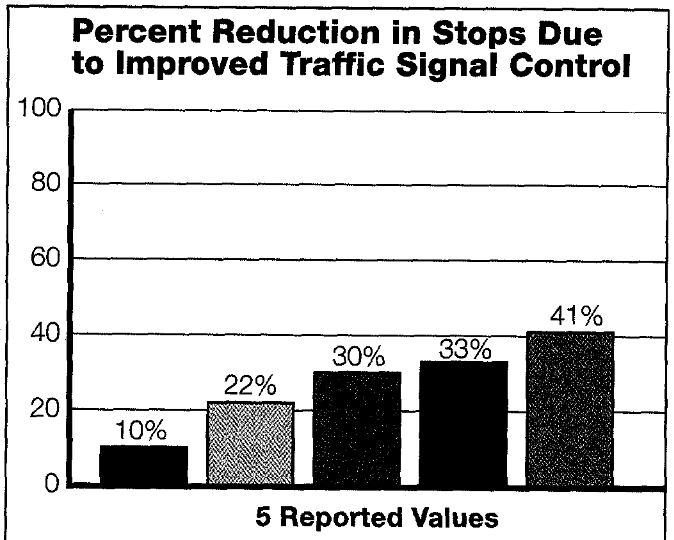

Figure 2-4: Reported Values of Stop Reductions under Improved Traffic Signal Control

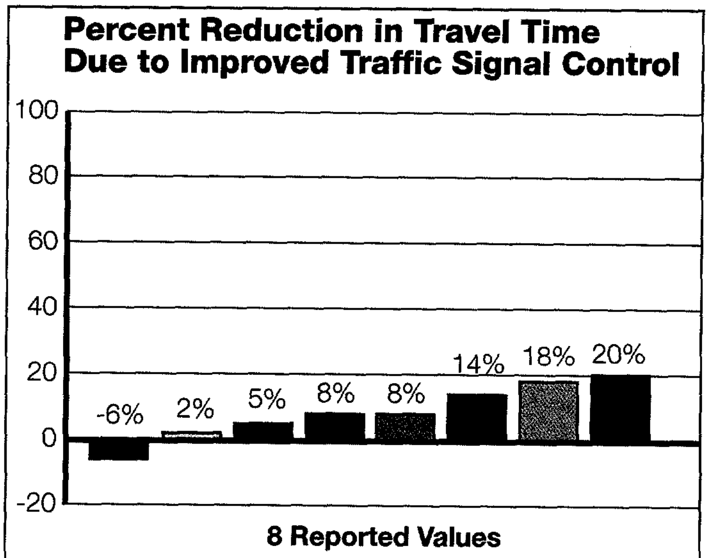

Figure 2-5: Travel Time Reduction with Improved Traffic Signal Control

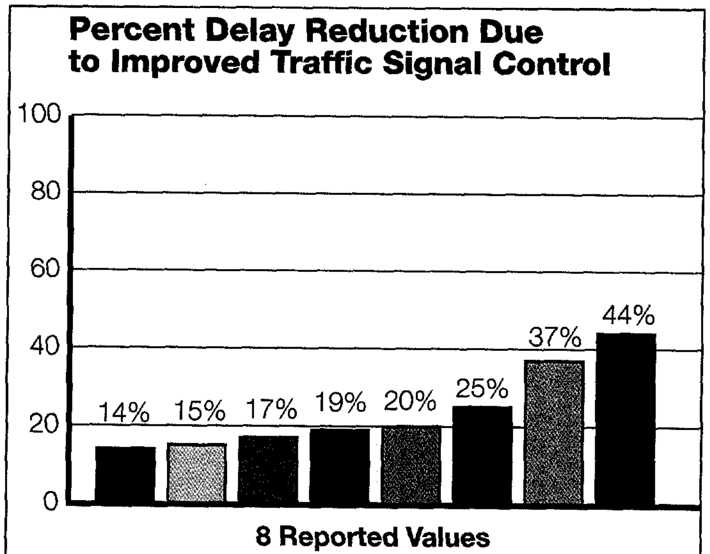

Figure 2-6: Delay Reduction with Improved Traffic Signal Control

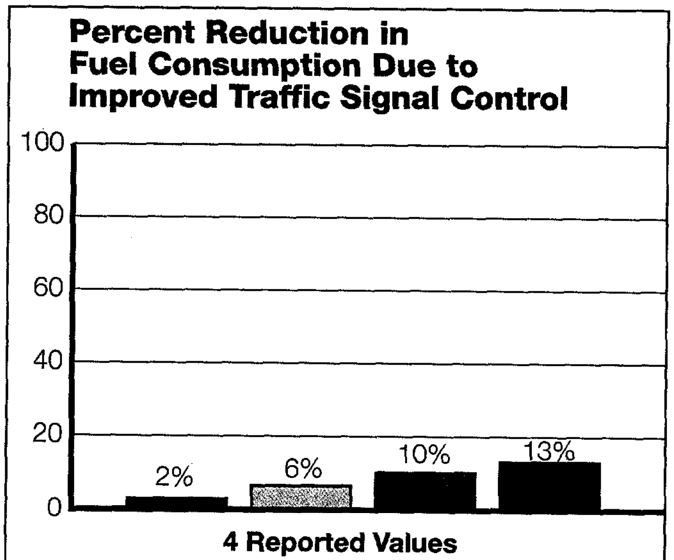

Figure 2-7: Fuel Consumption Reductions Due to Improved Traffic Signal Control

15 Glassco, R, *et al. Studies of Potential Intelligent Transportation System Benefits Using Traffic Simulation Modeling: Volume 2.* Mitretek Systems Report (MTR 1997-31). June 1997.

16 City of Los Angeles Department of Transportation 1994.

17 Abdel-Rahim, Ahmed, William C. Taylor and Ashok Bangia. "The Impact of SCATS on Travel Time and Delay". Eighth ITS America Annual Meeting. Detroit Michigan. 4-7 May 1998.

18 Peck, C. *et al.* 1999.

19 Zimmerman, C., et al. *Phoenix Metropolitan Model Deployment Initiative Evaluation Report.* FHWA Report (FHWA OP-00-015). Washington, DC: 2000.

20 Beteille, *et al.* 1997.

21 Siemens Automotive 1995.

22 City of Los Angeles Department of Transportation 1994.

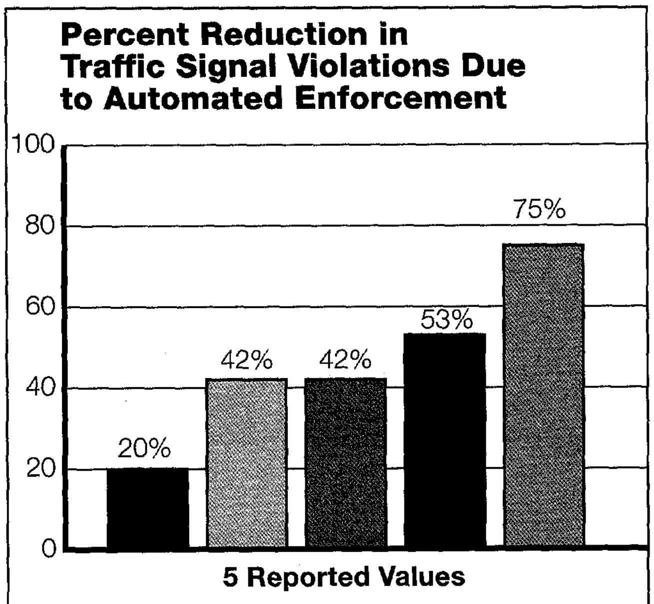

Figure 2-8: Reduction in Signal Violations Due to Automated Enforcement

emissions of nitrous oxides. This is expected because increases in average vehicle speeds due to improved traffic flows lead to increased production of nitrous oxides while decreasing other harmful emissions.

Figure 2-8 illustrates the reduction in violations recorded by several cities that have implemented automated enforcement of traffic signals. While violation reductions cannot be directly translated into safety impacts of the enforcement systems, reductions in the number of vehicles violating the signal do indicate a positive impact on safety at the enforcement locations. The wide variety of violation reductions represented in the figure below is likely due to both differences in individual enforcement programs as well as measurement differences between areas. The following section discusses most recent evaluations of implementations of arterial management systems.

2.1.2 Summary of Most Recent Evaluations

The City of Sao Paulo, Brazil, installed an adaptive signal control system along the commuter, commercial, and service route on the Av. Lins de Vasconcelos. The system resulted in an average reduction in delay of 14.4% for a 15-hour period while speeds improved 14%. Mid-day average speeds improved 25%. Floating vehicle analysis of a similar implementation at 107 intersections in Madrid, Spain, found a decrease in average travel time of 5%. Flow through the area was improved by reducing the number of stops by 10% and delay by 19%.[23]

A computer modeling effort investigated the potential impact of coordinating traffic signal timing plans among several jurisdictions along a congested arterial corridor leading into Seattle. The results of the model determined that coordinating the fixed signal timing plans along the corridor would result in a 7% reduction in vehicle delay, with no adverse impacts to cross-streets. The model also indicated that there would be no statistically significant change in vehicle emissions, the expected number of crashes along the corridor would fall by 2.5%, and the expected number of fatal crashes in a ten-year period would fall by 1.1%.[24]

Anaheim, California, implemented the SCOOT adaptive signal control system within a three-square-mile area of the city containing four major event centers. Notably, this implementation required the SCOOT system to use existing mid-block vehicle detectors rather than detectors at the preferred locations near upstream intersections. A before-and-after evaluation of five test routes through the area found that the change in travel times ranged from a decrease of 10% to an increase of 15%. More circuitous routes involving more of the SCOOT system saw travel time changes from a 2% reduction up to an increase of 6%. The relative performance against the baseline system was better when there were no events at the centers being studied.[25]

[23] Peck, C. *et al.* 1999.

[24] Jensen, M., *et al. Metropolitan Model Deployment Initiative Seattle Evaluation Report: Final Draft.* Federal Highway Administration Report (FHWA-OP-00-020). Washington, DC: May 2000.

[25] McNally, M.G., *et al. Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test: Executive Summary.* California PATH Research Report (Report No. UCB-ITS-PRR-99-18). Berkeley, CA: July 1999.

These results indicate inconsistent performance of the SCOOT system with vehicle detectors in non-standard locations. Also, as implemented in Anaheim, the system appears to have more difficulty adapting to the extreme variations in traffic volume that occur during major events than the more minor variations present in daily operation.

A study at the busiest intersection along a transit route in Eindhoven, the Netherlands, investigated the impact of several transit signal priority strategies on the delay experienced by buses and private vehicle traffic. The study found that average total vehicular delay experienced during the three busiest hours at the intersection increased by 40 seconds per vehicle under absolute priority. There was no significant change in delay with the buses operating under conditional priority, which only provides a green signal for buses running behind schedule. This pattern held true for all of the surveyed hours, with absolute priority causing large delays to other traffic, while conditional priority caused little, if any, additional delay. Buses experienced an average of 27 seconds of delay without priority. This figure dropped to 3 seconds per bus with absolute priority. During conditional priority, the bus delay fell between these values. Ninety percent of all buses received zero-delay service under absolute priority. Only 74% of the late buses experienced zero-delay service under conditional priority, indicating a need to improve the system's determination of a vehicle's on-time status.[26] These results indicate that additional control of on-time schedule performance provided to transit operators by conditional priority causes little additional delay to other traffic.

A second study in Eindhoven investigated the impact of the signal priority system on the deviation of transit vehicles from schedule. Field measurements of vehicle schedule adherence before and after a major intersection found a 28-second difference in the change in average schedule deviation as vehicles traversed the intersection. Vehicles traveling through the intersection under conditional priority achieved a 17-second improvement in the average absolute value of schedule deviation, while vehicles traveling without the benefit of conditional priority generally increased the average value of schedule deviation by 11 seconds. Simulation to investigate the impact of various priority strategies along a four-stop hypothetical transit route also indicated that conditional priority had a positive impact on schedule reliability as measured through deviations from scheduled running times.[27] The improvements in schedule reliability for buses at the intersection studied and along the simulated route indicate the enhanced control of on-time schedule performance that conditional signal priority can provide to transit operators.

A simulation of emergency vehicle signal preemption at three intersections near a suburban hospital outside Washington, DC found that the average travel times of other vehicles using the intersections increased a minimal, though statistically significant, 2.4% when signals were preempted for emergency vehicles.[28]

Studies at intersections in Los Angeles, California; Rochester, New York; and Phoenix, Arizona; indicate that automated pedestrian detection at traffic signals can improve safety. In general, there was an 81% decrease in the number of pedestrians crossing during a DON'T WALK with the addition of automated detection to intersections with operational push buttons. Conflicts encountered by pedestrians during the first half of the crossing were reduced 89% while conflicts for the second half were reduced 42%. Conflicts associated with right-turning vehicles were reduced 40%. All other conflicts were reduced 76%. Most of these reductions are attributed to reliable detection and signal extension for pedestrians in the process of crossing, not those waiting at the curb to

[26] Furth, Peter G. and Theo H.J. Muller. "Conditional Bus Priority at Signalized Intersections." 79th Annual Meeting of the Transportation Research Board. Washington, DC. 9-13 January 2000.

[27] Muller, Theo and Peter Furth. "Integrating Bus Service Planning with Analysis, Operational Control, and Performance Monitoring." ITS America 2000 Annual Meeting. Boston, Massachusetts. 1-4 May 2000.

[28] Bullock, Darcy, J. Morales, B. Sanderson. *Evaluation of Emergency Vehicle Signal Preemption on the Route 7 Virginia Corridor.* Federal Highway Administration Report (Publication No. FHWA-RD-99-070). Washington, DC: July 1999.

cross. In Los Angeles, using automated detection only with the push-button taped over, there was a 7% to 17% increase in conflicts, likely due to pedestrians not realizing that the signal was automatically detecting their presence.[29]

Floating-car studies of the coordination of traffic signals across two jurisdictions in the Phoenix, Arizona, metropolitan area found a 6.2% increase in vehicle speeds, 1.6% reduction in fuel consumption, a 1.2% increase in CO emissions and no significant change in HC or NO_x emissions, and a reduction in the crash risk along the mainline of 6.7%. The field trial and floating-car data collection, included coordination of signal cycle lengths for 8 of the 21 signals along the corridor. Simulation studies of traffic along the entire corridor indicated that the benefits experienced by test vehicles at the coordinated intersections could be counteracted by delays experienced at earlier signals along the corridor. Simulation of signal coordination along the full length of the corridor indicated potential benefits of a 21% reduction in AM peak delay. Results for independent optimizations without coordination indicated a potential for a 16% reduction in AM peak delay.[30]

Three European projects investigated the impacts of public transit priority systems. Each of the projects demonstrated significant delay or travel time reductions for transit vehicles. Travel time reductions ranged from 5 to 15% in the QUARTET PLUS and TABASCO projects, with field trials in Toulouse, France; Turin, Italy; Gothenburg, Sweden; and Munich, Germany. The project in Valencia, Spain, found a 30% reduction in delay for vehicles already behind schedule. These reductions led to improvements in operating efficiency, which in turn provide significant cost reductions for operators.[31]

After implementing traffic signal priority for a light-rail transit (LRT) line along an urban arterial in Toronto, Canada, system operators were able to remove one vehicle from service and maintain the same level of service to passengers along the corridor, reducing operating expenses. The system operators have some concern over the operation of the system at LRT stops just prior to signalized intersections and have also received complaints regarding increases in pedestrian delay due to the signal priority system.[32]

A transit priority system implemented on a bus line along an urban arterial in Vancouver, British Columbia, has reduced the variability of travel time experienced by buses along the route by 29% in the AM peak and 59% during the PM peak. The system uses conditional priority permitting transit vehicles to obtain signal priority if they are behind schedule as the vehicle approaches the intersection.[33]

The automated red-light enforcement system in New York, N.Y. began operation in 1993 with enforcement at 15 intersections; by 1998, 30 intersections were included in the program.[34] A 1997 Urban Transportation Monitor article cited a 20% reduction in violations over the life of the program.[35]

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[29] Hughes, Ronald, H. Huang, & C. Zeger. "ITS and Pedestrian Safety at Signalized Intersections." *ITS Quarterly.* Vol. VII, No. 2. Washington DC: ITS America, Spring/Summer 1999.

[30] Zimmerman 2000.

[31] *Telematics Applications Programme - Transport Areas' Results (4th Funding Programme).* European Commission Report. July 2000. [http://www.trentel.org/transport/frame1.htm]

[32] Cima, Bart, *et al.* "Transit Signal Priority: A Comparison of Recent and Future Implementations." ITE 2000 Annual Meeting. Nashville, Tennessee. 6-10 August 2000.

[33] Cima 2000.

[34] Institute of Transportation Engineers. *Automated Enforcement in Transportation.* ITE Report (Publication No. IR-100). Washington, DC: ITE, December 1999.

[35] "Cameras Reduce Red Light Running Violations by 20-30%." *The Urban Transportation Monitor.* May 23, 1997.

Howard County, Maryland, deployed red-light enforcement cameras at two intersections during a demonstration project. During the demonstration project, violators received warning notices in the mail. There was a 23% reduction in the number of violations per day at the two intersections after the public information campaign and mailing of violation notices commenced.[36] More recent reports from Howard County indicate that the program is successful. One intersection experienced 15 collisions during the year prior to implementation of a camera and eight collisions in the year following the installation. While the result was recorded too soon after implementation to be statistically significant, it may indicate a positive impact on safety at the intersections. Driver behavior has changed significantly at all intersections in Howard County where the cameras have been installed. The red light violation rate has dropped approximately 53% across all intersections with enforcement systems.[37]

Between the first and sixth months of operation of red light enforcement cameras in San Francisco, California, the ratio of violating vehicles to the total number of vehicles using the monitored approach decreased by 42%. San Francisco also implemented a public awareness campaign about the problem of red-light running at the time the automated enforcement program began.[38]

Oxnard, California, implemented an automated enforcement program very similar to the one implemented in San Francisco and also began a corresponding public awareness program. The enforcement program in Oxnard also achieved a 42% reduction in violations after only several months.[39]

Victoria, Australia, began its red-light enforcement program in 1983 and in 1999 the program included 35 cameras rotated among 132 sites around the Melbourne metropolitan area. A 1988 study found a 30% reduction in right-angle crashes due to the program and a 10.4% reduction in casualties from crashes.[40] A second study, in 1995, found that the number of red-light violations had been reduced between 35% and 60%, right-angle crashes decreased 32%, right-angle turning crashes decreased by 25%, and rear-end crashes decreased by 30.8%; however, rear-end turning crashes increased by 28.2%.[41]

In the first year of operations, crashes caused by running red lights were reduced 9% at camera-monitored intersections in the city of Charlotte, North Carolina. The system has resulted in a violation reduction of 75%. Charlotte believes that giving the program a name and an extensive marketing program has been a major factor in the success of the system.[42]

A 1999 survey of drivers in five U.S. cities that employ red-light running enforcement cameras and five cities that do not use the cameras found that drivers in both groups of cities strongly favor the use of enforcement cameras. In cities currently using the cameras, 80% of drivers approved of their use, while in cities that do not have enforcement cameras, 76% of drivers were in favor of the systems.[43]

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[36] ITE 1999.

[37] Hansen, Lt. Glenn. "Can We Increase the Capability of Red Light Cameras?" *ITS World.* January/February 2000.

[38] ITE 1999.

[39] ITE 1999.

[40] Victoria Traffic Camera Office. Website, [http://home.vicnet.net.au/~tco/index.htm]. Melbourne, Australia: TCO, 1999. cited in ITE 1999.

[41] Coleman, Janet A. et al. *FHWA Study tour for Speed Management and Enforcement Technology.* Federal Highway Administration Report (FHWA-PL-96-006). Washington, DC: February 1996. *cited in* ITE 1999.

[42] "Branding is the Name of the Game in Enforcement." *ITS International.* May/June 2000. pp. 66-67.

[43] Retting, Richard A. "Reducing Red Light Running Crashes: A Research Perspective." 2000 ITE Annual Meeting. Nashville, Tennessee. 6-10 August 2000.

2.2 FREEWAY MANAGEMENT SYSTEMS

There are three major ITS functions that make up freeway management systems. Two of these are the monitoring and control of freeway operations. Monitoring and surveillance can be used to implement control and management strategies such as ramp metering rates and variable speed limits based on observed freeway conditions. The third function consists of displaying or providing information to the motorist. Motorists may receive this information in several ways, including Dynamic Message Signs (DMS), Highway Advisory Radio (HAR), In-vehicle Signing (IVS), or specialized information transmitted only to a specific set of vehicles. Other methods of providing traveler information are discussed in Section 2.9 of this report.

Freeway Management Systems

- Traffic Surveillance
  - Incident Detection
- Traffic Control
  - Lane Control
    - Speed Limits
    - Lane Use
  - Freeway Entrance
    - Ramp Metering
- Information Display
  - Dynamic Message Signs
  - Highway Advisory Radio
  - Specialized Information
    - Ramp Rollover
    - Downhill
  - In-Vehicle Signing
- Public Safety
  - Enforcement

Figure 2-9: Taxonomy for Freeway Management Systems

Automated enforcement is also used to improve safety by increasing compliance with speed limits and reducing aggressive driving. Figure 2-9 shows the classification of benefits data for freeway management systems.

For a summary of freeway management systems deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

2.2.1 Summary of Freeway Management Impacts

Data collected for freeway management systems have shown improvements to safety, reductions in travel time and delay, increased throughput, and flow improvements. Although each of these measures contains data points, only a few contain enough data for comparison and analysis. Much of the collected data have been related to ramp metering. Ramp metering has shown significant reductions in crashes, crash rates, and increased mainline travel speed. Table 2-1 outlines much of the ramp metering results collected and is compiled from data presented in previous benefits reports along with the new data highlighted in Section 2.2.2.

Location	Number of Meters	Freeway Coverage (km)	Crash Reduction	Secondary Crash Reduction	Crash Rate Reduction	Increased Speed	Reduced Travel Time	Delay Reduction	Increased Throughput Capacity	Demand Increase	Increased Traffic Volume
National Survey			15-50%			16-62%	48.0%		8-22%	17-25%	
Seattle, WA					62.0%						10-100%
St. Paul, Minnesota						60%		11-93 hours	30.0%	2.9-7.2%	
Portland, OR	58		43%			60%	39.1%			25.0%	
Minneapolis/St. Paul, MN	6	8	24%		38.0%	16%					
Minneapolis, MN	39	27	27%		38.0%	30%				32.0%	
Minneapolis/St. Paul, MN*	430	338	21%			8%	22.0%		16.3%		9.9%
Seattle, WA	22				39.0%	20%	52.3%			86.0%	
Denver, CO	5		50%							18.5%	
Detroit, MI	28		50%			8%				12.5%	
Austin, TX	3	4.2				60%				7.9%	
Long Island, NY						9%					
Long Island, NY	70	207	15%			13%					
Amsterdam			35%	46%	23.0%						
German Autobahn			29%		20.0%						
Glasgow, Scotland									5.0%		

* Figures from the 2000 Minneapolis/St. Paul evaluation converted as needed from impact of ramp metering shutdown to impact of ramp metering operation.

Table 2-1: Summary of Ramp Metering Impacts

There are several interesting points to note from the table. First, there are three different evaluations of the ramp meters in the Minneapolis region. The difference between these studies is that the second one examined more than six times the number of meters and over three times the number of freeway kilometers as the first, yet both studies show similar results in crash and crash rate reductions. The most recent study, completed in February 2001, assesses the impact of the entire ramp metering system and also measured a similar crash reduction percentage. The variety of travel speed improvements between the studies is likely due to differences in the operating conditions of the different study areas under investigation. For example, speed improvements might be very significant in bottleneck areas, but modest at less congested interchanges.

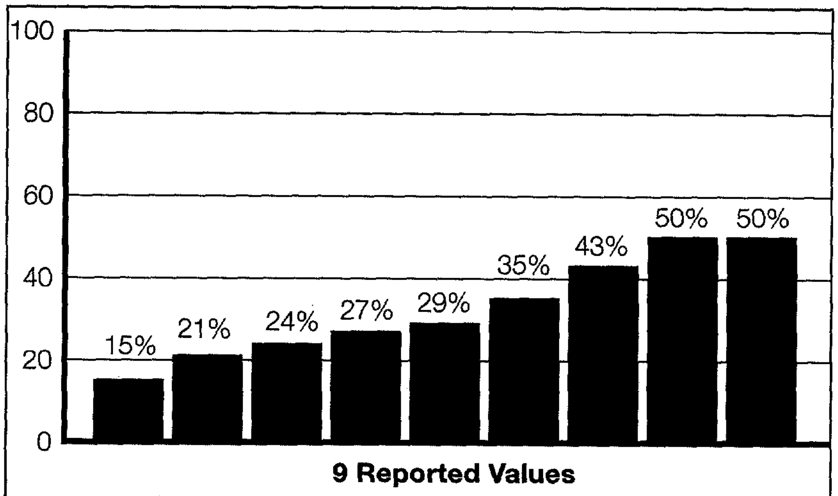


Figure 2-10: Percent Crash Reduction Due to Ramp Metering

Figure 2-10 summarizes the measured values for the percent reduction in crashes due to ramp metering of freeways in metropolitan areas. Ramp metering can reduce crashes by reducing the probability of sideswipes in merge areas. Also reduced are rear-end collisions that occur as vehicles slow to allow others to merge, or because vehicles on the

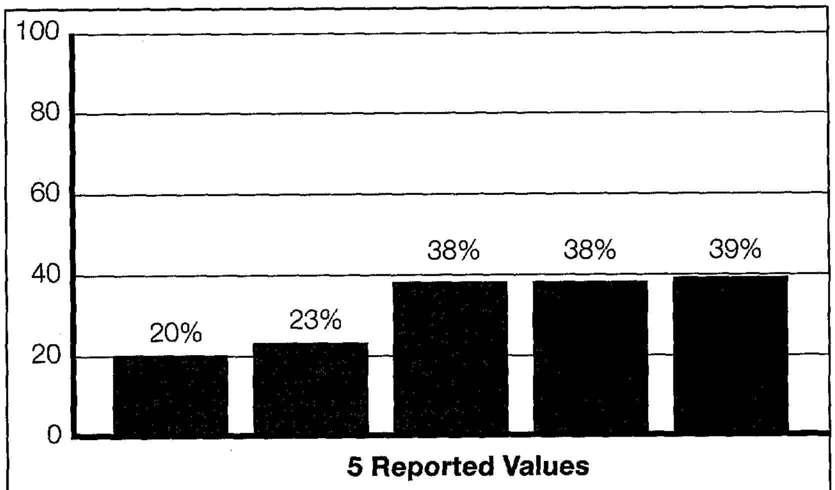


Figure 2-11: Percent Reduction in Crash Rates Due to Ramp Metering

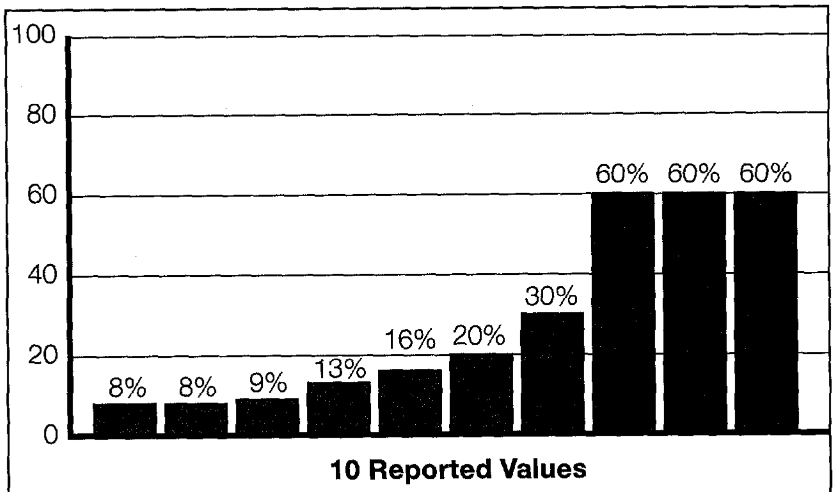


Figure 2-12: Percent Increases in Speed Due to Ramp Metering

ramp cannot merge. These reductions occur in both the mainline lanes as well as on ramps. Values of crash reductions reported range from 15% to 50%. Figure 2-11 illustrates the data reflecting reduction in crash rates, which range from 20% to 39%.

Ramp metering also has a positive impact on freeway speeds as summarized in Figure 2-12. These increases in speed imply significant travel time or delay savings. The range of speed increase is from 8% to 60%. This large range may be due to the differences in flow rates, geometric design of the freeway, number of meters, ramp spacing, or the length of freeway being measured. The figure also shows that the data appear to be grouped around low (8% to 16%) and high (60%) thresholds.

2.2.2 Summary of Most Recent Evaluations

A recent study performed for the Minnesota Department of Transportation (Mn/DOT) revealed the impacts of shutting down the extensive ramp metering system on Minneapolis-St. Paul area freeways for a six-week evaluation period. The study analyzed data collected along four test corridors chosen to represent typical freeway configurations and conditions across the region. The study collected a variety of data using several data collection techniques, including probe vehicles operating during peak periods, traffic volume counts from existing traffic detectors and temporary installations, crash statistics, and traveler surveys. Results from the evaluation indicate the generally positive impact of ramp meters:

- A 9% reduction in freeway volume without ramp meters, and a 14% reduction in peak period throughput (VMT).
- An average 22% decrease in freeway travel times with the meters on. The increase in travel times without the system more than offsets the elimination of ramp delays. Meters result in an annual systemwide savings of 25,121 hours.

- A 7% reduction in freeway speeds without meters.
- A 26% increase in crashes without meters.

Market research data collection results showed a number of changes in attitudes among area travelers that occurred once meters were shut down.

- Most survey respondents believed that traffic conditions worsened.
- Support for modifying the metering system, such as using faster cycle times, having shorter operating hours, and using fewer meters, increased from 55% to 69% of respondents.

Analysis of the benefits and costs of the ramp metering system showed that when the costs of the entire congestion management system (including changeable message signs, traveler information, and other components) are factored in, the benefit/cost ratio for ramp metering is 5:1. When ramp meter benefits are compared to only those costs directly associated with ramp metering, the benefit/cost ratio is 15:1.[44]

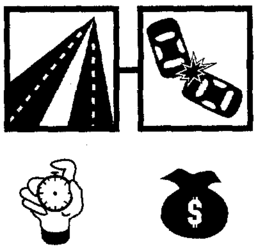
A computer simulation study estimated the impact of a freeway management system on incident-related congestion in Fargo, North Dakota. Results of the investigation revealed an 8% decrease in network travel times and an 8% increase in speeds with the installation of dynamic message signs to notify travelers of alternative routes around incidents. The study also investigated the integration of the freeway management system with an adaptive signal control system on adjacent arterial roadways to accommodate diverted traffic, which resulted in an 18% reduction in travel times and a 21% increase in vehicle speeds during incident conditions.[45]

A study to examine the safety impacts and public opinion of the pilot Aggressive Driver Imaging and Enforcement (ADIE) program along the Capital Beltway in Montgomery and Prince George's Counties, Maryland, was conducted in 1998. The study used motorist surveys and speed measurements to determine the effectiveness of the imaging and enforcement system and a related media campaign carried out in November 1997. The system began operation in January 1998. The ADIE system consisted of a specially trained police officer using several ITS technologies mounted in a dedicated police vehicle positioned at appropriate locations along the Beltway. The system allowed the officer to identify aggressive drivers and trigger an automated camera that photographed both the entire vehicle and the license plate. Warnings were mailed to offenders, but no penalties were assessed during the pilot program. Before-and-after surveys were distributed to residents in the vicinity of the Beltway, Commercial Vehicle companies operating on the Beltway, and truck drivers at a rest area near the I-95 and I-495 Interchange in Maryland. Approximately 4,000 copies of the survey were distributed in April 1997 and again after the system began operation, with approximately 1,000 surveys returned each time. Survey results indicated that the media campaign was effective in increasing motorists' awareness of the aggressive driving problem, with the number of respondents indicating that aggressive driving was a problem increasing from 19% to 54%. Prior to implementation, 82% of survey respondents favored using video technology for traffic enforcement, while 86% favored its use afterwards. The study analyzed speed data from automatic recording stations at three locations along the Beltway to assess the impact of the system on vehicle speeds. There was a significant reduction in the number

[44] Cambridge Systematics, Inc. *Twin Cities Ramp Meter Evaluation.* Prepared for Minnesota Department of Transportation. February 1, 2001.

[45] Birst, Shawn and Ayman Smadi. "An Evaluation of ITS for Incident Management in Second-Tier Cities: A Fargo, ND Case Study." ITE 2000 Annual Meeting. Nashville, Tennessee. 6-10 August 2000.

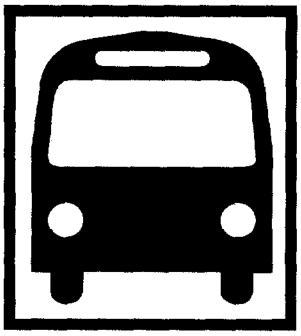
of vehicles exceeding 60 mph (the Beltway speed limit is 55 mph) in March 1998 when compared to March 1997. Two of the three recording stations showed decreases while one revealed an increase in the number of vehicles traveling at more than 60 mph. Due to the incomplete development of the system, related technical problems hindering its application, and the short duration of the study period, overall safety impacts such as any reduction in the number of crashes could not be assessed.[46]



The traffic management system for Highway 401 in Metropolitan Toronto is known as COMPASS. COMPASS was developed to provide safe and efficient travel on 42 km of the highway. It consists of loop detectors to determine traffic speed, volume, and density along with closed circuit television (CCTV) cameras monitoring the highway. Incident conditions and delay are monitored along the highway. Information is then sent to dynamic message signs, the media, fax machines, and radio stations for delivery to travelers. The benefits of the system include a cost savings of over $10 million per year from reduced crash, travel time, and vehicle operation costs. Incident duration has been reduced from an average 86 minutes to 30 minutes, while average incident-related delay is reduced by 537 vehicle hours per incident systemwide. This results in over 300,000 vehicle-hours of delay saved each year. By displaying messages on the dynamic message signs, 200 crashes per year are also saved. Average speeds have also improved between 7% and 19%.[47]

[46] Daniel Consultants, Inc. *Aggressive Driver Imaging and Enforcement: Evaluation Report - Impact of Media Campaign and Effects on Safety and Productivity.* Report prepared for Science Applications International Corporation. September 11, 1998.

[47] Institute of Transportation Engineers. *1996 ITS Tour Report: Eastern North America & 1996 ITS World Congress.* ITE Report. Washington, DC: 1997.



2.3 TRANSIT MANAGEMENT SYSTEMS

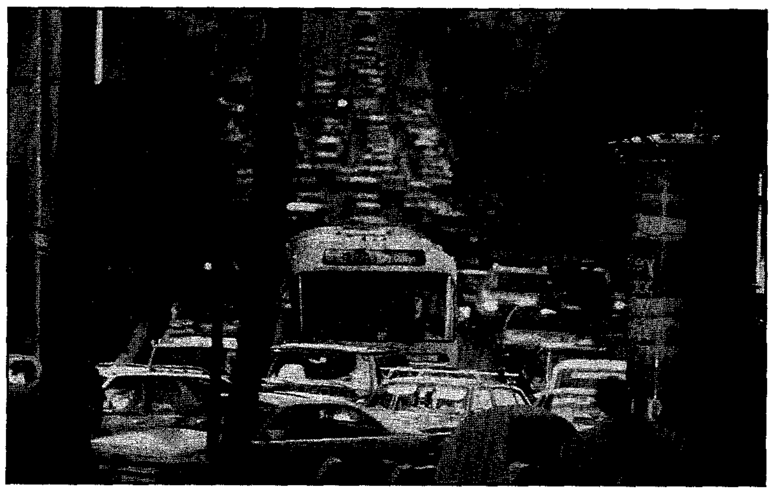
Advanced Public Transportation Systems (APTS) include a number of ITS applications that can help transit agencies increase the safety and operational efficiency of the nation's transit systems. Remote monitoring of transit vehicle status and passenger activity helps to provide additional safety and security to passengers. Transit ITS services also assist operators in maintaining vehicle fleets. Vehicle self-diagnostics can alert mechanics of unexpected mechanical problems as well as routine maintenance needs. Automated vehicle location (AVL) and computer aided dispatch (CAD) can improve scheduling activities and schedule adherence. Figure 2-13 shows the taxonomy for benefits of transit management systems described in this section. Transit signal priority and electronic fare payment, discussed in sections 2.1 and 2.7, respectively, also provide significant benefits to transit operations.

Transit management systems have demonstrated that they are capable of reducing travel time both by improving the operation of the vehicles and the overall operation of the transportation network. Transit management systems improve schedule adherence and the dissemination of schedule and route information to passengers, resulting in a reduction in passenger wait time and improvement in transfer coordination. Also, APTS applications reduce the cost of system operations by improving staff productivity and the utilization of facilities and equipment.

Transit Management Systems

- → Transit Management
  - → Maintenance
  - → Automated Vehicle Location
  - → ParaTransit
    - → Computer Aided Dispatch
- → Transit Information
  - → Display - Audio/Visual
    - → Traveler Information

Figure 2-13: Taxonomy of Transit Management Systems



For a summary of transit management systems deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

2.3.1 Summary of Transit Management System Impacts

Combined CAD/AVL systems are some of the most widely deployed APTS applications.[48] Analysis of these systems has begun to reveal their quantifiable impacts on schedule reliability. The unique conditions faced in each application of CAD/AVL and the different performance metrics used in evaluating them, make summary assessments of the systems difficult. Figure 2-14 contains three reported values of the impact of these systems on the on-time performance of the transit systems that implemented them. Results in the figure are from evaluations of implementations in Portland, Oregon;[49] Kansas City, Missouri;[50] and Baltimore, Maryland.[51] Regardless of the performance measures used, many system evaluations indicate positive impacts on schedule reliability and operational efficiency. In addition to improvements in on-time performance, CAD/AVL systems allow agencies to gain the most from their vehicle resources, providing valuable information for operational control strategies that can reduce the number of vehicles necessary to provide the required level of service to transit passengers.

Passenger surveys reveal high levels of customer satisfaction with implemented APTS applications. Transit patrons appreciate the benefits of improved communication of transit route and schedule information through a variety of information dissemination technologies. The various surveillance technologies used in APTS also improve the safety and security of transit systems.

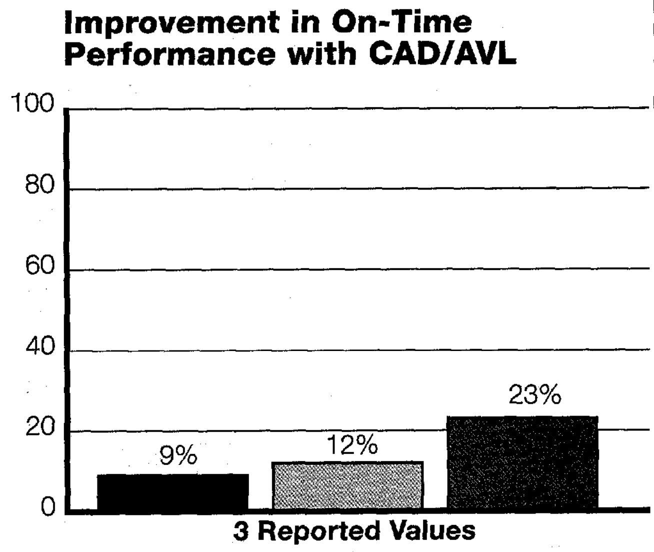


Figure 2-14: Improvement in On-Time Performance with CAD/AVL

2.3.2 Summary of Most Recent Evaluations

Metro Online, a website providing route and schedule information for the Seattle area bus system, provides a valuable service to its users. Many users indicated, in a survey, that they had been long-term users of this ITS service. Several recommended potential improvements to the site, including improvements to the route planning and transfer sections of the site.[52]

Customer satisfaction was also high for Transit Watch, a system that provides actual arrival and departure information for passengers at key transit centers in Seattle. Transit riders indicated that they would like to see the information available at places where travel decisions are made. While the system did not increase the satisfaction of existing riders with the transit system as a whole, new riders were pleased with the system, which may indicate that it could help the bus network retain new transit patrons.[53]

[48] Casey, R., *et al. Advanced Public Transportation Systems: The State of the Art - Update – 96.* Federal Transit Administration Report. Washington, DC: January 1996.

[49] Strathman, James G., *et al.* "Service Reliability Impacts of Computer-Aided Dispatching and Automatic Vehicle Location Technology: A Tri-Met Case Study." *Transportation Quarterly.* Vol. 54 No. 3, Summer 2000. pp. 85-100.

[50] Giugno, M. *Milwaukee County Transit System: Status Report.* July 1995.

[51] "Intelligent Time Savers, Life Savers." *ITS Update.* December 1997.

[52] Jensen, M., *et al.* 2000.

[53] Jensen, M., *et al.* 2000.

Since implementing an Automatic Vehicle Location (AVL) system, the Denver Regional Transportation District (RTD) has provided its transit customers with higher quality service. The RTD decreased the number of vehicles that arrived at stops early by 12% between 1992 and 1997. The number of passengers per vehicle that arrived at stops late decreased by 21%. Customer complaints decreased by 26% per 100,000 boardings, in part due to improved schedule adherence by RTD. Provision of a silent alarm feature with the AVL system has helped improve the safety of the transit system. Passenger assaults per 100,000 passengers decreased by 33% between 1992 and 1997.[54]

The Outreach paratransit transportation broker in San Jose, California, realized significant benefits after implementing a digital geographic database, an Automatic Vehicle Location system on a portion of the vehicles under contract to Outreach, and an automatic scheduling and routing system. Outreach benefited from increased ridership, better on-time performance, and a $500,000 reduction in operating costs during the first year of operation. A study of the system revealed an increase in the number of shared rides from 38% to 55% of all rides provided, a reduction in the size of the paratransit fleet from 200 to 130 vehicles, and a reduction in the cost per passenger mile from $4.88 to $3.72.[55]

Portland, Oregon's, Tri-Met System achieved a 9.4% improvement in on-time performance after implementing an AVL and CAD systems. The variability in the headways between buses decreased by 5% after implementation of the improvements. No significant change was measured in the average run times for buses along the routes, with run times remaining about 1% longer than their scheduled values. The average coefficient of variability for bus run times did improve by 18%, however, and no route experienced an increase in run time variability. These benefits indicated by the comparison of before and after data are consistent with the improved control available to transit supervisors after the implementation of the AVL and CAD systems. A modeling effort using the collected data to control for external impacts on bus run times determined that the impact of the AVL/CAD system was to improve running times by 3.4%. Increases in the average number of stops made, the scheduled headways of buses, and the average departure delay of buses beginning their routes counteracted this improvement. This indicates that the AVL/CAD system allowed the Tri-Met to accommodate these changing conditions without increasing bus run times.[56]

A demonstration system in Valencia, Spain, incorporated a dynamic bus scheduling system and a remote maintenance monitoring system. This system led to efficiency gains including a 35% reduction in the time it takes to create a bus schedule and a 10% improvement in the cost-effectiveness of schedules through reductions in waiting time. The maintenance system enabled a 20% to 30% reduction in the time required to detect and correct vehicle faults.[57]

A European study investigating the use of Travel Dispatch Centers for coordinating and managing paratransit services demonstrated significant cost savings over previous implementations. Accounting for implementation costs, the system resulted in a 2% to 3% annual decrease in costs to provide paratransit service, which compares favorably with the previous experiences of a 15% annual increase.[58]

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[54] Weatherford, Matt. *Assessment of the Denver Regional Transportation District Automatic Vehicle Location System.* U.S. Department of Transportation Report (DOT-VNTSC-FTA-00-04). Cambridge, MA: John A. Volpe National Transportation Center, August 2000.

[55] Taylor, Steven T. "Reaching Out with ITS." *ITS World.* March/April 1997. pp. 24-28.

[56] Strathman 2000.

[57] *Telematics Applications Programme* 2000.

[58] *Telematics Applications Programme* 2000.

A 1998 survey of transit riders in Ann Arbor, Michigan, assessed the impact of several transit safety and security enhancements including on-board video surveillance, emergency phones, video cameras at transit centers, enhanced lighting at transfer centers, and increased police presence. The surveillance systems were the safety enhancement most often noticed by respondents. The on-board cameras were noticed by 70% of the respondents and the transit center cameras by 63%. Additional police presence was noticed by 51% of respondents, while the increased lighting was noticed by 42%. Only 28% of those responding to the survey noticed the emergency phones installed at transfer centers. Respondents rated all improvements very highly when asked the degree to which each improved their sense of security.[59]

2.4 INCIDENT MANAGEMENT SYSTEMS

It is projected that by the year 2005, incident-related congestion will cost the U.S. public over $75 billion in lost productivity and will result in over 8.4 billion gallons of wasted fuel.[60] Incident management systems can reduce these effects by decreasing the time to detect incidents, reducing the time for responding vehicles to arrive, and by decreasing the time required to return the facility to normal conditions. Freeway service patrols, which began prior to the emergence of ITS technologies, but are being incorporated into traffic management centers, significantly reduce the time to clear incidents, especially minor incidents. It is generally understood that incident management systems are implemented concurrently with freeway management systems, but it is important to keep in mind that arterials can be included in incident management programs as well. Coverage of arterials by incident management programs is increasing, particularly in areas with well-established programs. The classification of benefits data for incident management systems is summarized in Figure 2-15.

For a summary of incident management systems deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

Incident Management Systems

- Surveillance
- Detection
- Response
  - Patrols

Figure 2-15: Taxonomy for Incident Management Systems

2.4.1 Summary of Incident Management Impacts

Table 2-2 summarizes much of the data collected for incident management impacts. Incident management programs have shown the potential to reduce the number of crashes and the time required for the detection and clearance of incidents. These programs show significant savings in the cost of congestion and are cost-effective. In addition, the public response to these programs has been very positive.

[59] Wallace, Richard R., *et al.* "Who Noticed, Who Cares? Passenger Reactions to Transit Safety Measures." *Transportation Research Record No. 1666*. Washington, DC: Transportation Research Board, 1999. pp. 133-138.

[60] Booz Allen, and Hamilton. *Incident Management: Detection, Verification and Traffic Management.* Filed Operational Test Cross-Cutting Study. September 1998.

Location	Reduced Incident Clearance Time	Reduced Response Time	Crash Reduction	Secondary Crash Reduction	Reduced Crash Rates	Cost Savings/yr. ($ millions)	Delay Savings (hrs/yr.)	Percent Delay Savings	Fuel Savings (Gallons)
Brooklyn, NY	66.0%								
Philadelphia, PA			40.0%						
San Antonio, TX		20.0%	35.0%	30.0%	41.0%	1.65	255,500		2,600
Japan				50.0%					
Houston, TX						8.40	572,095		
Denver, CO						0.95	95,000		
Atlanta, GA							2,000,000	5.00%	
Minnesota						1.40			
Atlanta, GA	38.0%								
Georgia Navigator	23 min	30.0%				44.60	547,000		

Table 2-2: Summary of Incident Management Data

Figures 2-16 and 2-17 show the range of values reported for cost savings and delay savings. Both of these measures are a function of the study area and implementation methodology. Thus the results show a wide range of possible values.

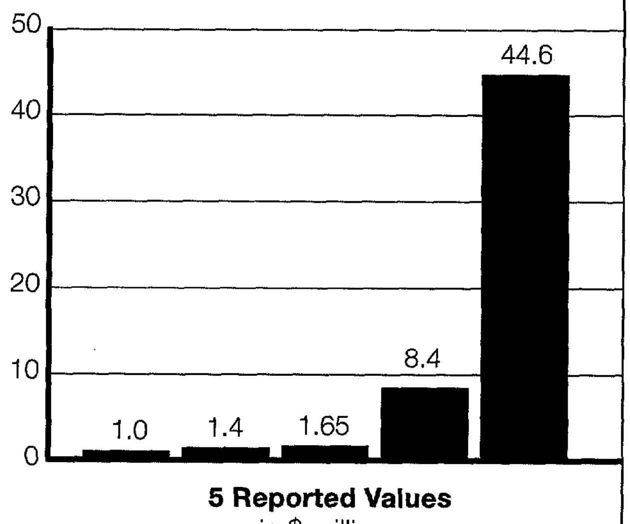


Figure 2-16: Reported Cost Savings Values for Incident Management

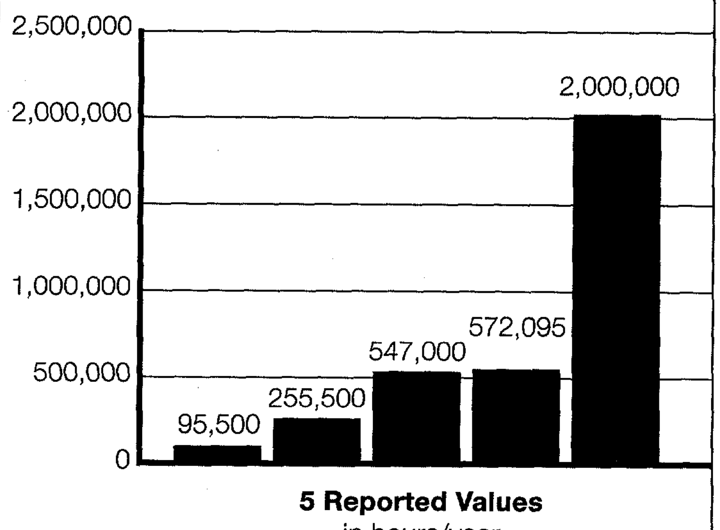
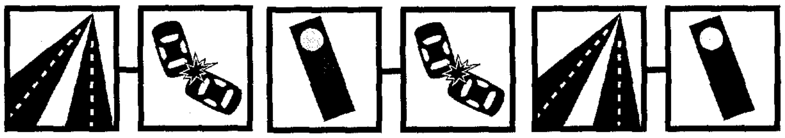
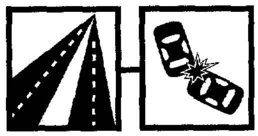


Figure 2-17: Reported Delay Savings Values for Incident Management

2.4.2 Summary of Most Recent Evaluations



Results from the evaluation of nine ITS implementation projects in the city of San Antonio, Texas, indicate that the most effective stand-alone implementation is incident management, which showed improvements in all impact measures assessed. DMS and arterial traffic signal control can provide additional improvement under many of these areas. For a particular corridor modeled during this study, optimum implementation of the integrated DMS and incident management result in a 5.7% decrease in delay, a 2.8% decrease in crashes, and a 1.2% decrease in fuel consumption annually. Integrated use of incident management, DMS and arterial traffic control can achieve an annual benefit of a 5.9% reduction in delay, a 2.0% decrease in crashes, and a 1.4% decrease in fuel consumption for travelers in the corridor. Focus group studies indicate that customers are satisfied with the DMS system, but do have some suggestions for improvement. Participants in the focus groups felt that DMS were a reliable source of traffic information, primarily when they are located close to the congestion or incident.[61]



Georgia's Intelligent Transportation System, "NAVIGATOR," includes several ITS elements. Elements include freeway management, incident management, transit management, electronic toll collection, electronic fare payment, and signal control. Operators can update dynamic message signs, ramp meters, the web site, and information kiosks quickly with a click of a mouse. Operators can also dispatch emergency response and change traffic signal timings. An evaluation of NAVIGATOR concentrated on the freeway and incident management system component and determined the following impacts:[62]

- Reduced response, identification, and dispatch time for incidents to two minutes (a 30% reduction).
- A 23-minute reduction in incident duration during 1997, resulting in cost savings of $44.6 million due to reduced delay time (did not include environmental benefits and benefits due to ramp metering during incidents).
- A 2.3:1 benefit/cost ratio for 1997 for the freeway and incident management components (based on a capital investment of $72 million for these components).
- Other benefits include air quality impact reductions, fuel consumption improvements, crash reduction, more efficient use of emergency services and more satisfied travelers.

Freeway service patrols have proven to be one of the most successful aspects of an incident management program for reducing incident detection time and duration. With a high benefit-cost ratio (ranging from 2:1 to 36.2:1), programs such as these are popular with the motoring public, politicians, and the agencies that support and operate them. Table 2-3 summarizes several benefit/cost ratios reported.[63]

[61] Carter, M. *et al. Metropolitan Model Deployment Initiative: San Antonio Evaluation Report (Final Draft).* FHWA Report (FHWA-OP-00-017). Washington, DC: May 2000.

[62] Presley, Michael, *et al. Calculating Benefits for NAVIGATOR: Georgia's Intelligent Transportation System.* Georgia Department of Transportation. September 1998.

[63] Fenno, David W., and Michael A. Ogden. "Freeway Services Patrols: A State of the Practice." 77th Annual Meeting of the Transportation Research Board. Washington, DC: January 1998.

Patrol Location	Patrol Name	Year Performed	B/C Ratings
Charlotte, NC	Incident Management Assistance Patrol	1993	3:1 to 7:1
Chicago, IL	Emergency Traffic Patrol	1990	17:1
Dallas, TX	Courtesy Patrol	1995	3.3:1 to 36.2:1
Denver, CO	Mile High Courtesy Patrol	1996	20:1 to 23:1
Detroit, MI	Freeway Courtesy Patrol	1995	14:1
Fresno, CA	Freeway Service Patrol	1995	12.5:1
Houston, TX	Motorist Assistance Program	1994	6.6:1 to 23.3:1
Los Angeles, CA	Metro Freeway Service Patrol	1993	11:1
Minneapolis, MN	Highway Helper	1995	5:1
New York & Westchester Co., NY	Highway Emergency Local Patrol	1995	23.5:1
Norfolk, VA	Safety Service Patrol	1995	2:1 to 2.5:1
Oakland, CA	Freeway Service Patrol	1991	3.5:1
Orange Co., CA	Freeway Service Patrol	1995	3:1
Riverside Co., CA	Freeway Service Patrol	1995	3:1
Sacramento, CA	Freeway Service Patrol	1995	5.5:1

(Adapted from Fenno and Ogden; see previous page)

Table 2-3: Results of Service Patrol Benefit-Cost Studies

2.5 EMERGENCY MANAGEMENT

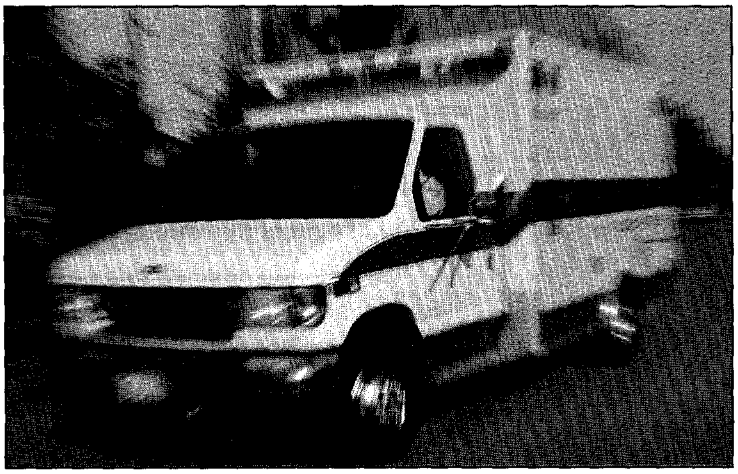
Benefits of emergency management include those derived from improved notification, dispatch, and guidance of emergency or other response equipment when an incident occurs, as shown in Figure 2-18. These benefits are sometimes highly dependent on the related implementations of incident management systems, which often detect the need for emergency response to incidents on the transportation network. Applications of ITS in emergency management typically consist of automatic vehicle location, computer aided dispatch, fleet management, and vehicle guidance systems. Each of these systems can help decrease the response time of emergency vehicles to incident scenes and aid public safety agencies in improving their operational efficiency.

The U.S. Department of Transportation recently initiated an ITS Public Safety program. As this program guides the development of ITS applications for public safety agencies such as police, fire, and rescue departments, improved information on the benefits of ITS to emergency management should develop.

Emergency Management

- Emergency Management
  - Dispatch
    - Automated Vehicle Location
    - Fleet Management
- Emergency Vehicle
  - Guidance

Figure 2-18: Taxonomy of Emergency Management



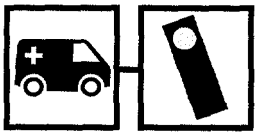
For a summary of emergency management systems deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

2.5.1 Summary of Emergency Management Impacts

Very few new data have been collected in the area of Emergency Management since the 1999 version of this report. Therefore, data highlighted in this section are from the 1999 report.

Albuquerque, New Mexico, uses a map-based computer-aided dispatch system in its ambulance fleet. The system allows the dispatch center to send ambulances to the exact location of an emergency and provide guidance on how to get there. As a result, the company's efficiency has increased by 10 to 15 percent.[64]

[64] Taylor, Steven T. "Helping Americans." *ITS World.* Jan/Feb 1997.

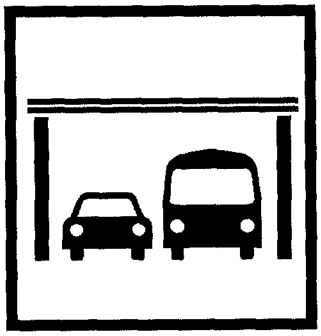


Palm Beach County, Florida, installed the Priority One signal preemption system. The system is used to connect the Global Positioning System (GPS) to its emergency vehicles. Prior to installation, it was predicted that the system could cut 20% from incident response time, depending on the intersection and time of day (as found by two Illinois towns using the system). As the vehicle approaches a traffic light, it transmits a signal interrupting the normal cycle, which allows the emergency vehicle to go through it without stopping. The GPS system will also allow dispatchers to figure out who is closer to an emergency. The cost is about $4000 per intersection and $2000 per vehicle.[65]

The Puget Sound Help Me (PuSHMe) Mayday System allowed a driver to immediately send a response center a notification and location of incidents along with the need for any assistance. The system includes two-way pagers and cellular telephones that transmit vehicle location, nature of the problem, and the priority level of the problem to a response center. The devices may also send automated signals when the driver may be incapable of manually initiating a signal. Ninety-five percent of drivers equipped with voice communications felt they were more secure, while just 70% of those with only data communications said that they were more secure with the system installed.[66]

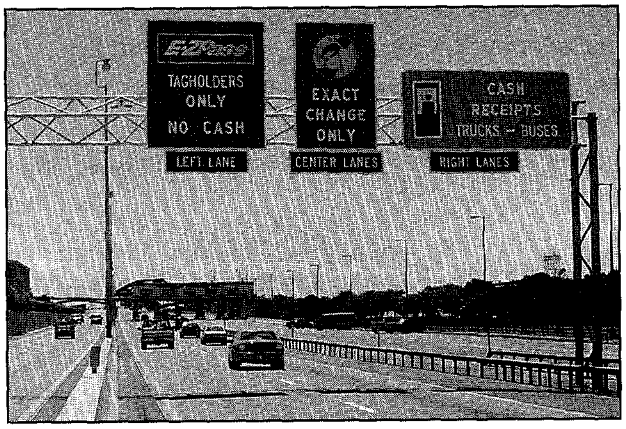
[65] Shifrel, Scott. "Satellites Around Globe May Save Lives Right Here." *The Palm Beach Post.* June 1, 1997.

[66] Haselkorn, M., *et al. Evaluation of PuSHMe Mayday System*: Final Report. June 19, 1997.



2.6 ELECTRONIC TOLL COLLECTION

Electronic Toll Collection (ETC) is one of the ITS program areas where little new benefits information is required. Benefits due to impacts on the cost of toll administration, management, and collection have been demonstrated. Vehicle delay reduction and throughput at toll plazas have been proven to be very high. Therefore, many of the recent reports for applications of ETC have concentrated on the accuracy and improvements in vehicle identification. Technologies are now capable of identifying vehicles at mainline speeds and at a high rate of accuracy. As a result, throughput is maximized, and delay that would occur at toll plazas is substantially reduced. There are also several efforts planned or underway to integrate these systems with other possible electronic payment systems, such as parking, transit fare payment, and drive-through window payment.



For a summary of electronic toll collection deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

2.6.1 Summary of Most Recent Evaluations

The evaluation of air quality benefits from implementing automatic vehicle identification (AVI) technology for electronic toll collection (ETC) has demonstrated positive results.

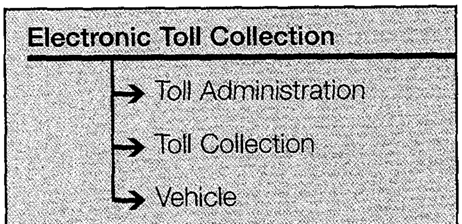


Figure 2-19: Taxonomy of Electronic Toll Collection

Located in Orlando, Florida, the Orlando-Orange County Expressway Authority (OOCEA) operates 11 mainline toll plazas. The busiest, the Holland East Toll Plaza, includes 14 toll lanes, nine of which are used for peak direction travel. A before-after study on the Express Pass (E-PASS) implementation of AVI-based ETC at the toll plaza was conducted to evaluate the reduction in vehicle emissions. Specifically, the reductions in Carbon Monoxide (CO), Hydrocarbons (HC), and Nitrogen Oxides (NO_X) were evaluated at the toll plaza. Data for the before AVI study were collected from August 1994 to October 1994. Arrival, departure, and speed data were collected during the peak morning hour (7-8 AM) for 14 days across all nine lanes in the westbound direction at the plaza. The after study data were collected from July 1996 to August 1996 during the peak morning hour (7-8 AM) in the westbound direction for 10 days. During this phase of the study, two dedicated lanes were configured for AVI/ETC operations. A comparison of before and after data revealed that the total average number of vehicles using the Holland East Toll Plaza during the peak hour increased by an average of 30% (1270 vehicles). Also, the average number of E-PASS users in the "after" study during the peak hour compared to the total volume is 40%. This is significant when considering that there were no E-PASS users in the "before" study. Using the MOBILE5a emission model and collected data, it was shown that even with the increased volumes at the Holland East Toll Plaza, vehicle emissions were reduced. The model estimated an overall average reduction in Carbon Monoxide by 7.29% (5.21 kg) and HC by 7.19% (0.40 kg), but NO_X increased by 33.77% (2.21 kg). Two additional scenarios were run to control for the growth in volumes on the results. The results remained consistent with the before-after study but demonstrated larger benefits.[67]

A cost-benefit analysis was undertaken as part of an Electronic Toll and Traffic Management (ETTM) feasibility study for Florida's Turnpike. Tamiami Plaza, the most heavily utilized of all the Turnpike mainline toll plazas, was selected for the study. For the 10% ETTM participation alternative, the benefit-to-cost (B/C) ratio was 2.03:1. For 30% ETTM, the B/C ratio was 2.29:1, and for 50% ETTM, the B/C ratio was 3.07:1.[68]

A report published in July 2000 summarizes the evaluation results for many types of ITS projects implemented in Europe between 1994 and 1998, including road pricing facilitated by electronic toll collection. Impact analysis of electronic toll collection in urban areas found up to a 17% reduction in traffic due to a road-pricing scheme. Most of the population was found to be against road pricing schemes, but if the programs were accompanied by reductions in vehicle and fuel taxes, acceptability rises to 61%.[69] These impacts are due to a road-pricing scheme facilitated by electronic toll collection, which could also be implemented without ETC, likely with a higher operating cost.

An assessment of the impact of a value-pricing program for two toll bridges in Lee County, Florida, was evaluated. The program allows motorists to pay a 50% discounted bridge toll during designated hours just outside the typical AM and PM peak periods. Only those drivers participating in the electronic prepayment program were eligible for the reduced tolls, as they were collected automatically via in-vehicle transponders mounted on the vehicle's windshield. A traveler survey of Lee County residents and collection of vehicle volume data at the toll plazas are the basis for the results presented in the study. The program began in August 1998. The analysis indicated that there was a significant shift in travelers away from the peak (full toll) periods to the non-peak (discounted toll) periods by those drivers who possessed the necessary transponders. A random telephone survey of 400 motorists in the county took place several months after the program began operation, between November 30 and December 5, 1998. Of the 193 travelers who had transponders in their vehicles, 38 (20%) responded that they had made changes in their travel due to the new program. Analysis indicated that travelers who modified their travel plans were more likely to be retired or working part-time. The survey results indicated that commuters were less likely to modify their schedules as a result of variable pricing than those with other trip purposes.[70] These impacts are also due to a road-pricing scheme facilitated by electronic toll collection, which could also be implemented without ETC, but probably with higher operating costs.

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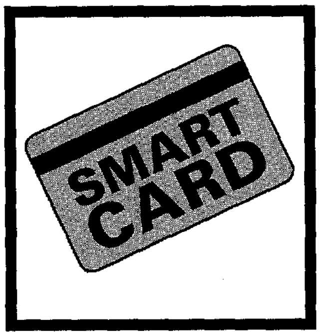
67 Klondzinski, J.G., *et al.* "Impacts of Electronic Toll Collection on Vehicle Emissions." 77th Annual Meeting of the Transportation Research Board. Washington, DC. January 1998.

68 Pietrzyk, Mike, *et al.* "Cost-Benefit Analysis of Electronic Toll and Traffic Management." Proceedings of the IVHS America 1992 Annual Meeting, Volume I. 1992.

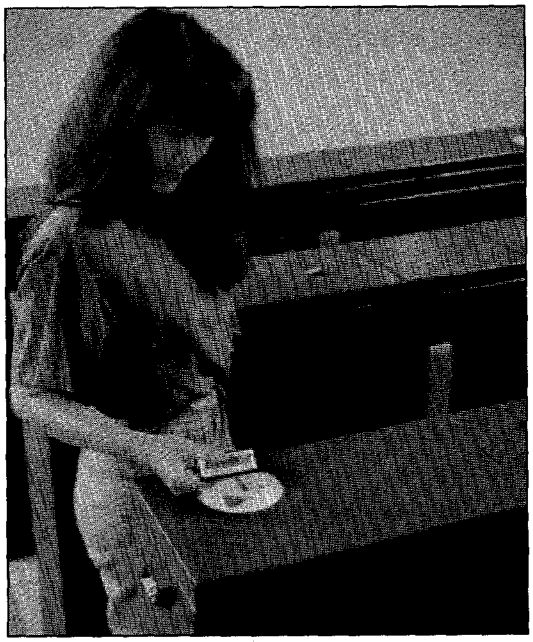
69 *Telematics Applications Programme* 2000.

70 Burris, Mark and Ashley Yelds. "Using ETC to Provide Variable Tolling: Some Real-World Results." ITS America 2000 Annual Meeting. Boston, Massachusetts. 1-4 May 2000.



2.7 ELECTRONIC FARE PAYMENT

Electronic fare payment is another one of the ITS program areas where little new benefits information has been required to justify implementation. Electronic fare payment tests, which address customer convenience and security, are ongoing in both bus and rail systems. Results indicate increased convenience to the customer, and significant cost savings in the administrative and money handling processes of the service providers. In some cases, it has also been reported that electronic fare payment can increase transit ridership.



For a summary of electronic fare payment deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

2.7.1 Summary of Most Recent Evaluations

A report published in July 2000 summarized the evaluation results for several ITS projects implemented in Europe between 1994 and 1998. Three projects discussed demonstrated the coordinated use of a smart card as a payment system for public transit, canteens, libraries, swimming pools, and/or other city services. User acceptance and satisfaction with these systems was very high, ranging from 71% to 87%.[71]

Other benefits reported for using electronic fare payment include:[72]

- Ventura County, California: Smart card system will save an estimated $9.5 million per year in reduced fare evasion; $5 million in reduced data collection costs, and $990,000 be eliminating transfer slips.
- New York City: Metro Card system will save an estimated $70 million per year in fare evasion, resulting in increased revenues of $34 million from merchant fees and revenue float, $140 million from unused value on the cards, and $49 million from increased ridership.
- New Jersey: estimated savings of $2.7 million in reduced handling costs of fare media, increased revenues of 12% after automated fare collection implementation.

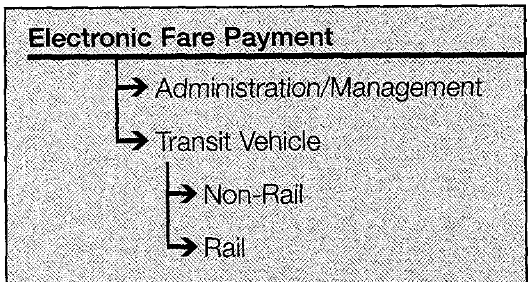
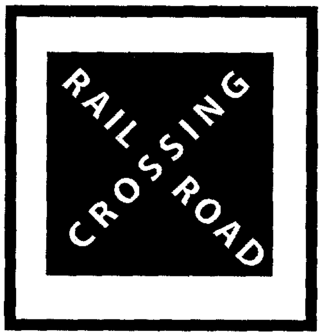


Figure 2-20: Taxonomy of Electronic Fare Payment

[71] *Telematics Applications Programme* 2000.

[72] *APTS Benefits*. Federal Transit Administration, November 1995.



2.8 HIGHWAY-RAIL INTERSECTIONS

The number of crashes that occur at highway-rail intersections (HRIs) on a yearly basis indicates the need for improvements at HRIs. In addition, the occasional spectacular crash including school buses or hazardous materials attracts national attention. However, the number of crashes occurring at HRIs has continued to decline over the last several years. As of January 2001, preliminary statistics show that from January to October 2000 2,776 HRI incidents were reported. This number is down 4.5% from that of the same period in 1999 (almost 14% from the same time period for 1997). The number of fatalities at HRIs increased from 331 to 351 (6%) between the two time periods. The general trend has been a decrease in HRI fatalities since 1997. HRI incident rates, calculated as the number of incidents multiplied by 1,000,000 then divided by the total number of train miles, has also shown a downward trend (18.8% since 1997).[73] It should be noted that these reductions are not related to ITS implementations. Instead they may be due to aggressive educational programs, such as "Operation Lifesaver" and the extensive use of the media to promote railroad safety issues over the last several years, as well as the physical reduction in the number of HRIs. The goal of the HRI user service is to further improve safety at these crossings and to improve the coordination between rail operations and traffic management functions.

Several operational tests involving coordinating traffic signals and notifying vehicles of approaching trains at intersections are currently being developed and implemented. A few pilot projects have produced results, but are insufficient to develop overall conclusions. Several other projects are being planned or are now in progress and are expected to produce quantitative data on benefits. Figure 2-21 illustrates the classification of benefits data for highway-rail intersections.

For a summary of highway-rail intersection systems deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

Highway-Rail Intersection

- Surveillance
- Control
  - Signals
- Display - Audio/Visual
  - Dynamic Message Signs
  - Highway Advisory Radio
  - In-Vehicle Signing
- Public Safety
  - Enforcement

Figure 2-21: Taxonomy for Highway-Rail Intersections

[73] Federal Rail Administration, Office of Safety.

2.8.1 Summary of Most Recent Evaluations

Minnesota DOT investigated the effectiveness of an in-vehicle train crossing warning system for school buses in Glencoe County. Transmitters mounted at five rail crossings transmitted warning signals to school buses in the vicinity of the crossings. The system notified drivers of both the presence of the crossing and whether or not a train was approaching. The evaluation of the project consisted of a questionnaire distributed to drivers and train operators. Drivers felt that the system enhanced awareness of the crossings and approaching trains; however, there were no significant changes in driver behavior. The drivers' confidence in the system's reliability was evenly divided.[74]

To reduce train horn noise at heavily used highway-rail grade crossings in Ames, Iowa, an automated horn system to warn motorists and pedestrians was installed in September 1998. Working in conjunction with existing gates and lights, two horns at each intersection are aligned to provide a more directed audible warning to the road and eliminate the need for the train horn under most circumstances. The evaluation examined the changes in noise levels in the area before and after installation of the automated horn system, and the opinions of residents, motorists, and locomotive engineers regarding the system. Results indicate that the area impacted by a noise level greater than 80 decibels decreased by 97% with the implementation of the automated system, from 171 acres to less than six acres. A mail-in resident survey taken two months before and two months after implementation determined that area residents were very satisfied with the system. 77% of residents indicated that the train horns had a "negative" or "very negative" impact on their quality of life before the automated system began operation. After implementation, 82% of residents responded that the automated horn was "no problem." The project also surveyed the locomotive engineers seven months after the automated horns began operation. Ninety-two percent of engineers indicated that the overall safety at the crossings was "about the same" or "safer" after the system was installed.[75]

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[74] *APTS Benefits* 1995.

[75] Gent, Steve J., *et al. Evaluation of an Automated Horn Warning System at Three Highway-Railroad Grade Crossings in Ames, Iowa.* Iowa Department of Transportation Report. undated.

2.9 REGIONAL MULTIMODAL TRAVELER INFORMATION

Providing traveler information regarding several modes of travel can be beneficial to both the traveler and service providers. Several transit agencies have started using traveler information kiosks and web sites to provide schedules, expected arrival times, expected trip times, and route planning services to patrons. Also, several traffic management centers are providing current traffic conditions and expected travel times using similar approaches. These services allow users to make a more informed decision for trip departures, routes, and mode of travel, especially in bad weather. They have been shown to increase transit usage, and may help to reduce congestion when travelers choose to defer or postpone trips, or to select alternate routes. Information on impacts of traveler information systems are separated into those which provide pre-trip and en-route information, as shown in Figure 2-22.

Regional Multimodal Traveler Information
- → Pre-trip Information
- → Enroute Information

Figure 2-22: Taxonomy for Regional Multimodal Traveler Information

For a summary of regional multimodal traveler information systems deployment in 78 of the largest U.S. cities, refer to www.itsdeployment.its.dot.gov.

2.9.1 Summary of Multimodal Traveler Information System Impacts

Evaluation of implemented traveler information systems reveals that the systems are well received by those who make use of them. Field tests providing traveler information through a variety of in-vehicle and portable devices have received widespread support from project participants. The number of travelers using the information systems generally represents a small portion of the total travelers in a region. Consequently, the evaluated systems have little, if any, impact on travel times across the regional transportation network. Individual users of the systems do perceive significant benefit from them and are generally satisfied with the service.

2.9.2 Summary of Most Recent Evaluations

The Advanced Regional Traffic Interactive Management and Information System (ARTIMIS) is a regional traffic management system provided by: the Kentucky Transportation Cabinet; Ohio Department of Transportation; FHWA; Ohio-Kentucky-Indiana Regional Council of Governments; and the City of Cincinnati. The system serves the Northern Kentucky and Cincinnati metropolitan areas. It contains an advanced transportation management system and an advanced traveler information system. In June 1995, a telephone information service began providing real-time traffic and travel condition information by specific route or route segment. Sources of up-to-date traffic information include video cameras, radar detectors, inductive loops, aircraft, service patrols, and drivers acting as probes. In a survey conducted in February and March 1999, ARTIMIS users rated the service very high in accuracy and ease of use. More than 99% of those surveyed said they benefited by avoiding traffic problems, saving time, reducing frustration, and arriving at destinations on time.[76]

[76] Clemons, J., L. Aultman-Hall, & S. Bowling. *ARTIMIS Telephone Travel Information Service: Current Use Patterns and User Satisfaction.* Kentucky Transportation Center, University of Kentucky, Department of Engineering. Lexington, KY: June 1999.

The customer satisfaction evaluation undertaken as a part of the Seattle Metropolitan Model Deployment Initiative (MMDI) determined, through focus groups, mail-in questionnaires, and web-based surveys, the response of Seattle area travelers to the various ITS improvements undertaken during the project. Overall, the three traveler information projects evaluated for customer satisfaction received high ratings from those travelers who made use of the systems. While the number of travelers influenced by the different systems varied widely, those who relied on each individual system generally found them to be useful. The Washington State Department of Transportation (WSDOT) traveler information web site received very favorable ratings from participants in an online survey accessible through the site. The web site used data from freeway loop detectors and video feeds to publish freeway segment travel speeds and incident data. Responses indicated that the site was frequently used for trips to and from work or school and that route changes were a significant response to information obtained from the site. Participants also indicated the benefit of reducing the stress of their journey. It is important to note that this was a voluntary survey, and that the responses of those who participated cannot be extended to represent all users of the web site. Data on the number of user sessions on the web site each day reflected a very large spike in usage during a winter weather event in December. This provides evidence of the importance of these types of systems during severe weather.[77]

The Seattle MMDI also implemented a traffic information television channel, known as Traffic TV. A focus group study and mailed questionnaire indicated that frequent users of the Traffic TV service rated it very highly, often using it to change travel routes for a particular journey. The survey also indicated that many of the users discovered the service while changing channels on their TV sets, indicating a low public awareness of the service.[78]

The Fastline system, designed to provide pre-trip and en-route traveler information in the Seattle area through Personal Digital Assistants (PDAs), experienced very low usage during the MMDI project. The lack of a significant marketing campaign and the limited number of PDAs supported by the software limited the market penetration of the service. Limited evidence of those travelers who did make use of this system indicated that they did change their behavior based on the information received.[79]

Additions and improvements to elements of San Antonio's traveler information system occurred during the MMDI, including new traveler information kiosks, improvements to the internet web site, and the installation of in-vehicle navigation (IVN) devices in vehicles operated by public agencies in the area. The kiosks provide information on incidents and congestion on the freeway network, transit schedules and fares, as well as navigational assistance. The web site provides freeway traffic information including incident locations, and links to transit schedule and fare information. The IVN devices provide navigational assistance, incorporating information on congestion, incidents, and railroad crossing status when planning trips.

Evaluation of the kiosks by a qualified expert indicated that the devices had several functional problems and were unlikely to be used often by travelers. Based on these results, the study did not perform further evaluation on the system impacts of the kiosks or customer satisfaction with them.

The web site evaluation indicates that usage of the site increased at a rate of 19% per year over the course of the nine-month evaluation period. Significant latent demand for the service was evidenced by dramatic increases in the

[77] Jensen, M., *et al.* 2000.

[78] Jensen, M., *et al.* 2000.

[79] Jensen, M., *et al.* 2000.

number of users accessing the site during two severe weather events over the evaluation period. Despite this growth, the relatively small number of travelers making use of the system led to no overall system impacts due to the web site. Modeling results indicate that individual travelers who use the web site prior to traveling along a particular corridor would receive annual benefits of a 5.4% reduction in delay, a 0.5 % reduction in crash rate, and a 1.8% reduction in fuel consumption.

The small number of publicly owned vehicles using the in-vehicle navigation (IVN) devices led to no system impact from these devices. Focus groups composed of drivers of vehicles equipped with the units indicated that the drivers most satisfied with the system were those who frequently drove different routes each day. Drivers often asked to drive to unfamiliar parts of the metropolitan area, such as paratransit drivers and police investigators, seemed to get the greatest benefit from the system. Public safety representatives did indicate that, with improvements to the method for entering destinations, the devices could be helpful in reducing response times of emergency vehicles. Modeling results indicate significant potential benefits for individuals using the devices. Over a one-year period a traveler using an IVN device could experience an 8.1% reduction in delay, a 4.6% reduction in the crash rate, and a 3% reduction in fuel consumption.[80]

The Seattle Wide-area Information for Travelers (SWIFT) Field Operational Test was an evaluation project of a large-scale advanced traveler information system. Deployed in the Seattle metropolitan area, SWIFT provided information on several transportation modes using three different devices. The devices included a wristwatch, an in-vehicle navigation system, and a portable PC-based system. Approximately 800 participants were used to evaluate the effectiveness and user acceptance of the three devices. The message watch received traffic information regarding user specified routes. The in-vehicle devices allowed users to request navigation instructions and provided traffic information and guidance along the selected route. Portable computers received information regarding traffic incidents, speed, congestion, and bus-location information. Users of the PC systems appeared to place a higher importance on the receipt of incident and congestion information and less on general information than users of other devices. In general, users of all three devices indicated that they found the information useful for making travel decisions. They also indicated a reduction in stress and travel time. Others changed routes based on provided information. Many users of the devices (especially Seiko Message Watch users) indicated that messages did not provide timely information. Some also questioned the accuracy of information displayed.[81]

A Finnish project found a high user acceptance of traveler information delivered via portable electronic devices sometimes called personal travel assistants (PTA). One-third of users reported changing mode based on information provided, and half changed route based on the information. Another project reported 40% stating they had changed mode based on information from the PTA, while 15% to 25% were willing to start their journey earlier.[82]

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[80] Carter, *et al.* 2000.

[81] Perez, William and Bruce Wetherby. *Seattle Wide-area Information For Travelers (SWIFT): Evaluation Summary*. Prepared for Washington State Department of Transportation by Science Application International Corporation, McLean, VA. January 5, 1999.

[82] *Telematics Applications Programme* 2000.

Evaluations of a series of European projects have provided information on the impacts of a variety of traveler information systems:[83]

Six projects provided information via public access terminals or fixed information terminals. User acceptance of the devices was high; cited projects report 79% to 95% of users finding the systems easy to use.

Internet information provided during six of the projects also had a high level of user acceptance, with 65% to 75% of respondents indicating that the information was easy to use and understand.

Several projects implemented in-vehicle navigation (IVN) devices. The CLEOPATRA project in Turin, Italy, demonstrated timesavings of more than 10% for cars equipped with the IVN devices. Customer satisfaction measures ranged from 50% to 75% of users expressing satisfaction with the devices. It should be noted, however, that 20% of the test drivers in Rotterdam, the Netherlands, expressed concern over being distracted from the driving task.

Several European studies focused on the impacts of messages displayed on DMS and the effectiveness of different information strategies. A collaborative study among the various projects found that 30% to 90% of drivers noticed DMS information. In Piraeus, Greece, the route guidance system combined with an integrated traffic control strategy led to a 16% reduction in travel time.

The Phoenix MMDI assessed customer satisfaction with the publicly operated Trailmaster web site and the Traffic Check cable TV traffic information service. Both the web site and television channel provided information on travel conditions on Phoenix area roadways by integrating data from the freeway management system and the Arizona Department of Transportation (ADOT) Roadway Closure and Restriction System.

Analysis of web site usage statistics indicated that the number of visits to the traveler information web site increased steadily during the evaluation period at a rate of 50% per year; evaluators expected this trend to continue. Overall, usage levels for the Phoenix web site were significantly lower than those experienced in Seattle, where traffic congestion is a more significant problem. Two focus group studies revealed Phoenix area travelers felt that congestion levels were not high enough to warrant frequent use of the site. Users did find the site helpful in assessing delays due to construction. Participants felt that the addition of congestion information for arterial roadways would make the site more useful.

A telephone survey was conducted to assess the impact of the traveler information cable TV channel implemented through the MMDI. Thirty-five thousand cable subscribers in Tempe, Arizona, received the Traffic Check television service during the evaluation period. Seven percent of these subscribers responded to a postcard survey inquiring about their use of the traffic information channel. Phone interviews were conducted with 723 subscribers, approximately half of whom had used the Traffic Check channel.

The phone interviews yielded several interesting results regarding the usage and customer satisfaction with Traffic Check. Of the participants who commute regularly, 93% report listening to traffic radio broadcasts for traveler information, 77% used traffic reports on local television, 75% use DMS, and 48% report using Traffic Check.

[83] *Telematics Applications Programme* 2000.

Survey results also indicate that pre-trip information in general may be less useful than en-route information; respondents typically indicated that information sources available en-route were most useful. Due to the small sample size, the authors of the evaluation report caution against extrapolating the survey results to a larger population.[84]

Mitretek Systems performed a three-step analysis of the effects of web-based traffic information and weather events on a mixed freeway/arterial network north of downtown Seattle. Analysis of Washington State's Department of Transportation (WSDOT's) traffic website usage data and observed weather data revealed that web site activity increased by 27% during a weather event and 69% during a snow event. This analysis also indicated that market penetration of the advanced traveler information system (ATIS) is not evenly distributed as originally assumed in the Seattle Metropolitan Model Deployment Initiative (MMDI) evaluation. A comparison analysis of non-uniform distribution results to MMDI baseline data found that for the "Freeway and Arterial" scenario, the total number of stops decreased by 6%, the adjusted travel time decreased by 1% percent, and the vehicle kilometers of travel did not appreciably change. The coefficient of variation for the "Freeway Only" scenarios decreased by a small but statistically significant 0.62 %, indicating that the travel time was more reliable. The results of a network analysis demonstrated that a non-uniform ATIS utilization rate related to severe weather has a small positive impact on roadway system efficiency.[85]

[84] Zimmerman 2000.

[85] Hardy, Matthew, *et al. Analyzing the Effects of Web-Based Traffic Information and Weather Events in the Seattle Puget Sound Region: Draft Report.* Mitretek Systems. October 2000.

2.10 INFORMATION MANAGEMENT

Data collected by ITS applications have great value as indications of the historical performance of a transportation system with regard to a variety of performance measures. In addition to supporting improvements in the operation of the ITS components, these data can also assist transportation planning, research, and safety management activities. The National ITS Program Plan released by the U.S. DOT in August 2000 describes ITS data archiving as addressing "the collection, storage and distribution of ITS data for transportation planning, administration, policy, operation, safety analyses, and research."[86] The recent addition of the Archived Data User Service (ADUS) and Archived Data Management System (ADMS) to the National ITS Architecture also indicates the value of retaining and analyzing data collected by ITS.

Operating agencies around the U.S. are in various stages of planning, implementing, and operating archived ITS data management systems. As these systems become a part of routine transportation planning, research, and operations activities, examples of their effectiveness will become available.

2.11 IMPACTS OF OTHER ITS APPLICATIONS IN METROPOLITAN AREAS

As the implementation of ITS in metropolitan areas continues, many implementing organizations are realizing that ITS applications initially designed for rural areas can also apply to situations faced in metropolitan areas. Examples of these applications include travel and tourism services, particularly systems providing information on travel services such as hotels and restaurants, and road weather management systems. Road weather management systems provide support to transportation agencies in collecting and disseminating information on road surface and weather conditions and managing weather-related maintenance activities, such as snow and ice removal during winter storms. These ITS applications can be beneficial in metropolitan as well as rural areas, and evaluations of urban applications of these systems are beginning to demonstrate positive impacts.

2.11.1 Summary of Most Recent Evaluations

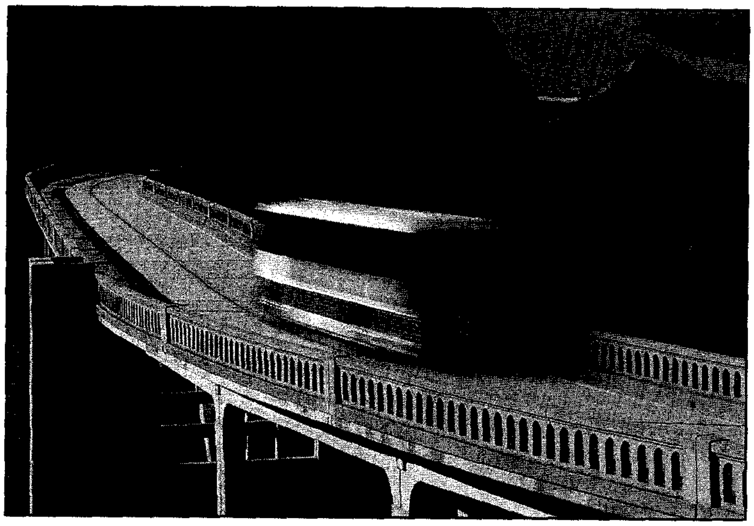
An automated motorist warning system (AMWS) in the city of Ft. Lauderdale, Florida warns motorists of the presence of wet pavement on a freeway ramp at an urban interchange. Comparing vehicle speed data from an evaluation period of six weeks prior to the activation of the AMWS and nine weeks following the activation reveals that, after the system was activated, average vehicle speeds were 10.2 mph (16.4 km/h) lower during heavy rain and 4.6 mph (7.4 km/h) lower during periods of light rain.[87]

[86] U.S. DOT ITS Joint Program Office. *The National Intelligent Transportation Systems Program Plan: Five Year Horizon.* Federal Highway Administration Report (FHWA-OP-00-008). August 2000.

[87] Pietrzyk, Michael C. "Are Simplistic Weather-Related Motorist Warning Systems 'All Wet'?" ITE 2000 Annual Meeting. Nashville, Tennessee. 6-10 August 2000.

3.0 BENEFITS OF RURAL ITS

Although rural areas account for a small portion of our nation's population, they contain a major portion of the transportation system. Eighty percent of the total U.S. road mileage is in rural areas, generating 40% of the vehicle miles traveled. Unlike urban areas, the rural environment has a different set of priorities and needs that reflect longer distances, lower traffic volumes, drivers unfamiliar with the surroundings, and longer emergency response times. Many of the ITS services provided in metropolitan areas can also be implemented in the rural environment. However, these services are sometimes required to cover much broader areas, or may become much more specialized in what they provide to the traveler.



The rural ITS initiative is a relatively new program, with increasing activity and funding levels over the last few years. Many rural operational tests and early deployments are currently underway. Some of these tests are starting to report impacts and benefits, while many are still undergoing development, implementation, or evaluation.

Rural ITS infrastructure is classified into seven major program areas. These areas include: crash prevention and security, emergency services, travel and tourism information, traffic management, transit and mobility services, operations and maintenance, and road weather management. Figure 3-0 summarizes these seven major program areas for Rural ITS.

Rural

- Crash Prevention & Security
- Emergency Services
- Travel and Tourism
- Traffic Management
- Transit and Mobility
- Operations and Maintenance
- Road Weather Management

Figure 3-0: Rural ITS Program Areas

3.1 CRASH PREVENTION AND SECURITY

One of the major goals of Rural ITS is to improve safety and security. Many of these services are intended to provide advance warning to motorists regarding dangerous roadway conditions. Others improve emergency response when incidents occur in rural areas. ITS applications can assist in evacuation and disaster management plans, where timely information is critical. Also included in this category of ITS are services such as remote surveillance and monitoring, which can enhance security at remote park-and-ride lots, rest areas, and similar facilities. Information from crash prevention and security applications can be used to implement roadway control strategies, such as emergency road closings or variable speed limits. Figure 3-1 depicts the classification of benefits related to crash prevention and security.

3.1.1 Summary of Most Recent Evaluations

California installed an advanced curve warning system at five curves along Interstate 5 in a rural mountainous area. Traffic volumes through the curves are low, ranging from an average daily traffic volume of 7,650 to 9,300 vehicles. The advanced warning systems consisted of dynamic message signs installed before each of the curves displaying warning messages about the upcoming curves. Using data from a radar unit mounted near the signs, the system also displays the actual speed of vehicles approaching the curves. An evaluation of the system included manual speed data collection and surveys of passenger vehicle and truck drivers at nearby rest areas and truck stops. Speed measurements were collected nine months prior to the system's installation and again two months, five months and 10 months after operation began. For three of the five installation sites, the reduction in the speed of trucks traveling through the curves was statistically significant for at least one of the three data collection periods after the warning signs began operation. The two sites that demonstrated a significant reduction in truck speeds for all three visits after installation had downgrades greater than five percent. The speed reductions were smaller for the later visits to the sites, possibly indicating the drivers were becoming accustomed to the signs and paying less attention to them. Passenger vehicles also demonstrated significant speed reductions at two of the five curves. Over 70% of the drivers surveyed indicated that the system was useful.[88]

Crash Prevention & Security

- Surveillance/Monitoring
  - Roadway Conditions
  - Environmental
  - Rail Intersections
  - Vehicle Intrusion
- Information Dissemination

Figure 3-1: Taxonomy for Crash Prevention and Security Applications

A Collision Countermeasure System (CCS) was designed for application at rural, unsignalized, two-way, stop-controlled intersections to improve safety. Operating on input from in-pavement loop detectors, the system automatically activates signs that graphically advise drivers of the presence and direction of approaching traffic. The system was installed on all approaches at the intersection of Aden Road and Fleetwood Drive in Aden, Virginia. A targeted analysis of data gathered on high-speed vehicles and those projected to collide with

[88] Tribbett, Lani, Patrick McGowen and John Mounce. *An Evaluation of Dynamic Curve Warning Systems in the Sacramento River Canyon: Final Report.* Prepared by the Western Transportation Institute, Montana State University, Bozeman for the California Department of Transportation New Technology and Research Program. April 2000.

another vehicle in the absence of an avoidance response, such as braking, indicated that the system eliminated the occurrence of projected times-to-collision shorter than an acceptable avoidance response time. For high-speed vehicles, average speed was reduced from 55.5 mph (89 kph) in the "before" phase to 54.8 mph (88 kph) in the "after" phase. Greater speed reductions observed immediately after sign installation were not sustained four months after operation began.[89] While the system does not appreciably reduce the speed of high-speed vehicles, it did eliminate the occurrence of vehicles approaching the intersection at a speed too high to avoid a collision when a vehicle was approaching on the intersecting roadway.

3.2 EMERGENCY SERVICES

Emergency Services address the detection of and response to incidents (such as vehicle crashes and hazardous material spills) and widespread events (such as evacuations and search and rescue missions). For rural areas, the response time for emergency medical services is greater than that typical in metropolitan areas resulting in more severe consequences or impacts. Data related to detection, mobilization and response, and information dissemination due to emergencies in rural areas are classified in the taxonomy as shown in Figure 3-2.

Emergency Services

- Detection
  - Call Centers
    - E911
    - Mayday
    - Call Boxes
  - Surveillance
    - Loop Detectors
    - Closed Circuit Television
- Mobilization & Response
  - Vehicle Tracking
  - Coordination
    - Interagency
- Information Dissemination
  - Dynamic Message Signs
  - Highway Advisory Radio

Figure 3-2: Taxonomy of Rural Emergency Services

Mobilization often involves a coordinated emergency response involving multiple agencies, various emergency centers, and numerous response plans. Coordination may include tracking of emergency vehicle fleets using automated vehicle location (AVL) technology, two-way communication between emergency vehicles and dispatchers, as well as interfaces with traffic and transit management systems and traveler information systems to disseminate information to affected agencies and the traveling public.

3.2.1 Summary of Most Recent Evaluations

In field tests conducted on the Ford-Lincoln Continental Remote Emergency Satellite Cellular Unit (RESCU) security system, drivers were able to make voice contact with a response center operator within one minute. On average, emergency response vehicles arrived within 11 minutes of system activation.[90]

The Georgia Department of Transportation installed a cellular telephone call box system along 39 miles (62.7 kilometers) of Interstate 185. During a six-month study period, system costs were roughly $120,000. Benefits associated with injury and fatality reductions were projected to be $289,000, while benefits associated with other incidents (e.g., flat tires, road debris, etc.) were estimated to be approximately $40,000. The benefit/cost ratio of the call box system was found to be 2.76:1.[91]

[89] Hanscom, Fred R. "Rural Stop-Sign Controlled Intersection Crash Countermeasure System Device Vehicle-Behavioral Evaluation." ITS America 2000 Annual Meeting. Boston, Massachusetts. 1-4 May 2000.

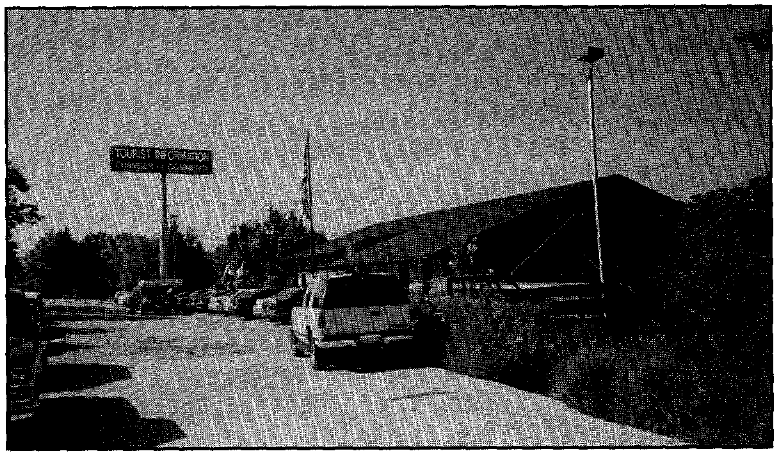
[90] Meyer, Harvey. "Safer Cars Make Safer Roads." *GEICO Direct.* Fall 1997. p 24 - 27.

[91] Kolb, Stephanie L., *et al.* "Evaluation of Georgia's Emergency Motorist Aid Call Box Pilot Project." ITS America 2000 Annual Meeting. Boston, Massachusetts. 1-4 May 2000.

3.3 TOURISM AND TRAVEL INFORMATION

Tourism and travel information focuses on the need of travelers to receive information in unfamiliar areas they are traveling through. These services address issues of mobility and traveler convenience, and may also improve the economy and productivity of rural and tourist areas.

Many of these services are in the planning and development stages, and few data regarding benefits for these services are available. Several national parks are currently undertaking operational tests or are examining the possible impacts of these services. Information services could include electronic yellow pages, transit, and parking availability. Mobility services such as a pre-trip route selection or en-route navigation are also included. Figure 3-3 summarizes the classification for benefits of tourism and travel information.



Travel and Tourism

- Traveler Information
  - Travel Services
    - Hotels, Restaurant
    - Tourist Info.
  - Route Advisory
    - Pre-trip
    - En-route
  - Travel conditions
- Revenue Collection
  - Electronic Payment

Figure 3-3: Taxonomy of Travel and Tourism Information

3.4 TRAFFIC MANAGEMENT

Through the application of ITS technologies, traffic management seeks to meet the needs of agencies tasked with operation and maintenance of rural roadways, improve mobility and driver safety, and foster economic development in rural areas. Figure 3-4 summarizes the classification of benefits data related to traffic surveillance, traffic control, and information dissemination.

Rural traffic management addresses unique traffic and safety issues related to occasional congestion. Dynamic control systems are often employed to monitor and manage traffic flow, including the flow of traffic through work areas.

Traffic Management

- Surveillance
  - Traffic Conditions
  - Road Conditions
  - Weather Conditions
- Traffic Control
  - Lane Control
    - Speed Limits
    - Lane Use
  - Work Zone
  - Signals
- Information Dissemination
  - Dynamic Message Signs
  - Highway Advisory Radio

Figure 3-4: Taxonomy of Rural Traffic Management

3.5 TRANSIT AND MOBILITY

The need for public transportation in rural areas is highlighted by the fact that 38% of the nation's rural residents have no access to public transit services and another 28% live in areas in which the level of transit service is negligible. Operating costs can be high, and providing these services in an efficient and effective manner can be difficult. Coordination between various providers can prove useful when trips consist of many different origins and uncommon destinations over wide areas. Advanced transit with AVL-assisted dispatching and routing along with fare payment strategies can also be used. Advanced ride sharing with improved parking information is also considered under this group of rural services. Data associated with public travel and mobility services are classified as shown in Figure 3-5.

Transit and Mobility

- Transit Management
  - Operations
  - Maintenance
  - Planning
- Traveler Information
- Electronic Payment
- Ride Sharing and Matching

Figure 3-5: Taxonomy for Transit and Mobility

3.5.1 Summary of Most Recent Evaluations

The Potomac and Rappahannock Transportation Commission operates demand-responsive transit to serve transit needs and commuter rail stations in the suburban fringe of the Washington, D.C. metropolitan area. The service also meets requirements of the Americans with Disabilities Act. Compared to a fixed route service and complementary paratransit service; the demand-responsive system is estimated to produce a 40% reduction in total cost.[92]

Use of coordinated paratransit with a dispatch system including AVL, which can coordinate trips among up to five agencies, has the potential to reduce fraud in Medicaid transportation by $11 million annually in the State of Florida.[93]

Public transportation providers in rural areas can achieve cost efficiencies by increasing ridership. The computer-assisted dispatching system in Sweetwater County, Wyoming, which allows same-day ride requests to be accepted, has contributed to an increase in ridership from 5,000 passengers monthly to 9,000 monthly without increasing the dispatch staff and a reduction of operational expense of 50% over a five-year period on a per passenger-mile basis.[94]

[92] Farwell, R. "Evaluation of OmniLink Demand Driven Transit Operations: Flex-Route Services." SG Associates, Annandale, Virginia. European Transport Forum. 1996.

[93] Ride Solutions. "Operational Strategies for Rural Transportation." Florida Coordinated Transportation System. Undated.

[94] Casey, R. "The Benefits of ITS Technologies for Rural Transit." Rural ITS Conference. September 1996.

3.6 OPERATIONS AND MAINTENANCE

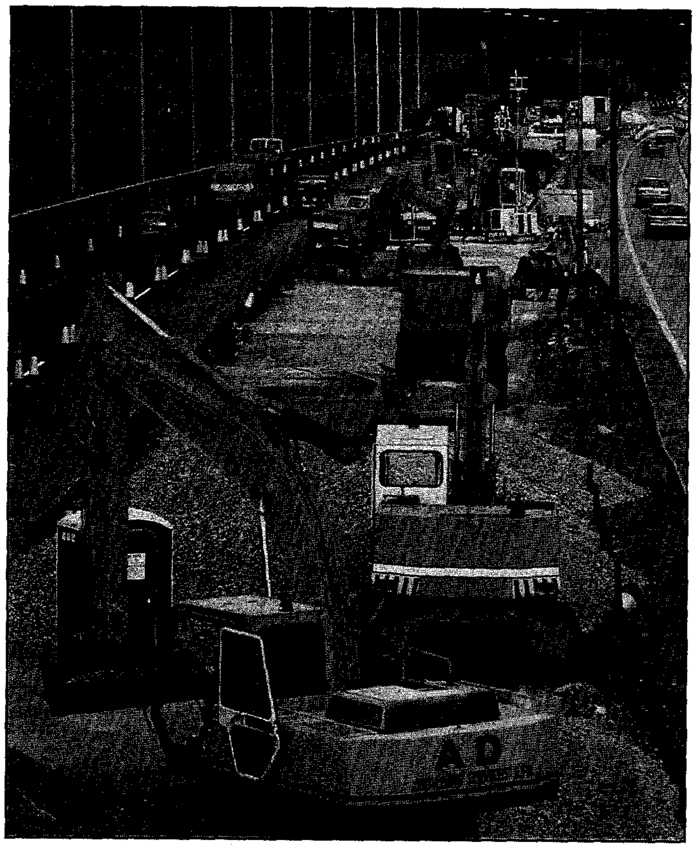
Operating and maintaining rural transportation systems can be costly. Managing traffic and monitoring roadway conditions in rural areas is often difficult due to distance, isolation, and the number of road miles. Many state DOTs are implementing ITS to better manage roadway maintenance efforts and enhance safety at rural work zones. ITS applications in operations and maintenance focus on integrated management of maintenance fleets, specialized service vehicles, hazardous road conditions remediation, and work zone safety. Systems and processes are required to monitor, analyze, and disseminate roadway/infrastructure data for operational, maintenance, and managerial uses. As implementation of these systems expands, quantified benefits of their use will become apparent. However, there are no benefits data available at this time. Figure 3-6 summarizes how benefits data regarding operation and maintenance are classified.

Winter weather maintenance applications fall under Road Weather Management, discussed in Section 3.7.

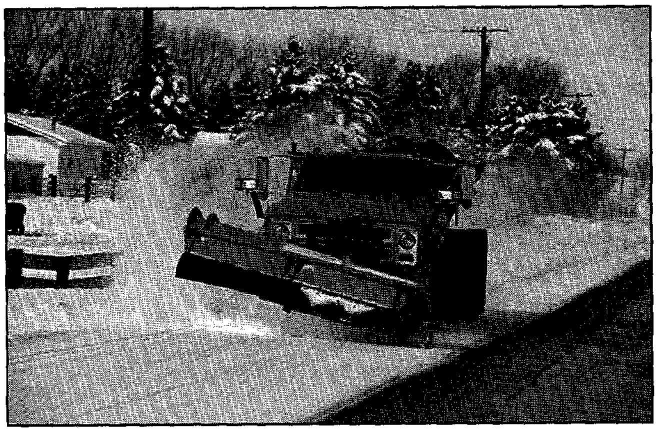
Operations and Maintenance

- Fleet Management
  - Automated Vehicle Location / Computer Aided Dispatch
- Infrastructure Management
- Weather Maintenance
- Work Zone Management
- Information Dissemination

Figure 3-6: Taxonomy for Operations and Maintenance



3.7 ROAD WEATHER MANAGEMENT



Adverse weather conditions pose a significant threat to the infrastructure and operation of our nation's roads. The Road Weather Management Program – formerly the Weather and Winter Mobility Program – was created to coordinate several weather-related activities in the Federal Highway Administration. The program focuses on development of improved road weather information systems (RWIS), development of improved winter maintenance technologies, and coordination of operations within and between state Departments of Transportation (DOTs). Figure 3-7 depicts the classification of data associated with Road Weather Management.

Road Weather Management

- Surveillance & Monitoring
  - Traffic Conditions
  - Road Surface Conditions
  - Weather Conditions
- Control
  - Speed Limit
  - Signals
  - Lane Use
- Response & Treatment
  - Winter Maintenance
    - Mobile
    - Fixed
  - Automated Vehicle Location
  - Interagency Coordination
- Information Dissemination

Figure 3-7: Taxonomy for Road Weather Management

3.7.1 Summary of Most Recent Evaluations

In Utah's Salt Lake Valley, a warning system comprised of visibility sensors and dynamic message signs (DMS), which display recommended speed limits under foggy conditions, increased average vehicle speeds by 15% while decreasing speed variability by 22 percent. Prior to installation of the warning system, the average vehicle speed was 54 mph (86.8 kph) with a standard deviation of 9.5 mph (15.3 kph). After system activation, the average speed increased to 62 mph (99.7 kph) while the standard deviation decreased 22% to 7.4 mph (11.9 kph). This reflects slower drivers increasing their speed to approach the recommended speed, decreasing the variability in vehicle speeds, resulting in an improvement in the safety of the facility.[95] The results of this study indicate that drivers do respond to advisory speeds posted under foggy conditions and that care should be taken in recommending advisory speeds to ensure that the posted speed is a safe travel speed.

[95] Perrin, Joseph, *et al.* "Effects of Variable Speed Limit Signs on Driver Behavior During Inclement Weather." Institute of Transportation Engineers (ITE) 2000 Annual Meeting. August 2000.

In the Netherlands, an automatic fog-signaling system with 20 sensors installed along 7.5 miles (12 kilometers) of the A16 motorway decreased vehicle speeds by approximately 5.6 mph (9 kph). Visibility distance was used to determine the appropriate speed limit, which was displayed on overhead DMS. For visibility distances between 230 and 460 feet (70 and 140 meters), the posted speed limit was 50 mph (80 kph). Visibility below 230 feet (70 meters) caused a 37 mph (60 kph) speed limit to be displayed. Due to the relationship between average speed and number of crashes, a decrease in crash frequency was also achieved.[96]

The Finnish National Road Administration (FinnRA) evaluated the profitability and effectiveness of an experimental RWIS installed along 8.7 miles (14 kilometers) of E18. The RWIS was comprised of 36 variable speed limit signs, five DMS, and two environmental sensor stations (ESS). In the winter, recommended speed limits were varied based upon pavement condition, precipitation, visibility, and wind. When speed limits were reduced, the reason for reduced speeds, such as "slippery road surface," was displayed on the DMS. It was estimated that the average speed decreased 0.4% to 1.4% due to the RWIS. The average yearly crash rate was projected to decrease by 8% to 25%. Annual costs were expected to decrease by $234,500. The anticipated benefit-cost ratio of the system was 1.1:1.0 and the remunerative rate of interest, which indicates how effective the use of invested capital has been, was 14%. These values show that the system has been socioeconomically profitable.[97]

The Idaho Storm Warning System field operational test assessed the performance of visibility sensors and analyzed the effectiveness of DMS in reducing vehicle speeds on Interstate 84 in southeastern Idaho. The evaluation of the operational test established performance capabilities of the system, baseline driver behavior, and driver behavior with the system operating during various road conditions. Researchers concluded that when travel conditions deteriorate due to poor visibility, high winds, wet or snow-covered pavement, or heavy precipitation; drivers reduce speeds without condition information from DMS. They further reduce speeds when DMS operate under high winds, high winds and moderate to heavy precipitation, and high winds and snow-covered pavement. When DMS were used, speeds were nearly 20 mph (32.2 kph) lower than when they were not used under these conditions.[98]

The Technical Research Centre of Finland conducted a two-phased driving simulator study to compare adverse road condition driver support systems. Three driver support systems were compared under winter conditions: no support system (i.e., typical winter driving feedback), an advanced driver information system including dynamic message signs (DMS) displaying "ICE" if road surface friction was low, and the weather-related intelligent speed adaptation (WISA) system, which prevented vehicles from exceeding a safe speed on icy road sections. The safe speed was computed based upon curve radius and surface friction. Average travel speeds with no driver support system and with the advanced driver information system were 39.4 mph (63.3 kph) and 38.8 mph (62.4 kph), respectively. With the advanced driver information system, speeds increased slightly

[96] Hogema, Jeroen H. and Richard van der Horst. "Evaluation of A16 Motorway Fog-Signaling System with Respect to Driving Behavior." *Transportation Research Record No.1563*. Washington, DC: National Academy Press, 1996.

[97] Yrjö, Pilla-Sihvila and Lähesmaa Jukka. *Weather Controlled Road and Investment Calculations*. Finnish National Road Administration, Southeastern Region. December 1995.

[98] Kyte, M., *et al. Idaho Storm Warning System Operational Test: Final Report*. Prepared for the Idaho Transportation Department. December 2000.

on bare road sections, but decreased more than necessary on icy sections due to overcompensation by drivers. It was concluded that driver adaptation to adverse conditions is inadequate, as they cannot accurately assess the degree of road surface friction. The WISA system was safer than the advanced driver information system, due to reduced variability in vehicle speeds and more uniform traffic flow. This reduced variability in vehicle speeds also led to a higher average speed, 40.2 mph (64.6 kph).[99]

A computer model quantified the benefits of using road weather information system (RWIS) data and the costs of reacting to weather conditions. Model results showed that the benefit-cost ratio for using weather and pavement condition forecast support was greater than 20.0:1.0. Level of service improvements on the order of 20% were computed.[100]

To improve the timeliness of winter maintenance activities, the Finnish National Road Administration has developed an automated information system that transmits actual and forecast weather and road surface information to maintenance personnel. The system includes 11 central stations, 150 environmental sensor stations (ESS) and over 200 workstations. De-icing activities reduced the duration of slippery road conditions by 10 to 30 minutes. It was anticipated that improved maintenance response would decrease crashes by three to 17 percent. The estimated cost savings due to crash reductions, delay reductions, and vehicle costs were $900,000 per year, $60,000 per year and $20,000 per year, respectively.[101]

The Indiana Department of Transportation utilizes the Computer Aided System for Planning Efficient Routes (CASPER) software to design winter maintenance routes. The number of routes needed to service the roadway network decreased by 8% to 10%. Winter maintenance cost reductions were anticipated to be between 11 million and 14 million dollars.[102]

The Wisconsin Department of Transportation (DOT) utilizes the Wisconsin Winter Weather System (WWWS) to dispatch winter maintenance equipment. The system utilizes ice detection systems and a snow forecasting model to plan work schedules, determine appropriate treatment times, identify treatment locations, and reduce costs. Cost reductions were achieved by minimizing personnel overtime costs and decreasing the use of de-icing chemicals. For each storm, the system is expected to reduce personnel costs by $144,000 and save roughly $75,000 due to reduced salt usage.[103]

[99] Peltola, Harri and Risto Kulmala. *Weather Related Intelligent Speed Adaption – Experience from a Simulator.* Technical Research Center of Finland. 2000.

[100] Boselly, S. Edward, III. "Benefit-Cost Assessment of the Utility of Road Weather Information Systems for Snow and Ice Control." *Transportation Research Record No.1352.* Washington, DC: National Academy Press, 1992.

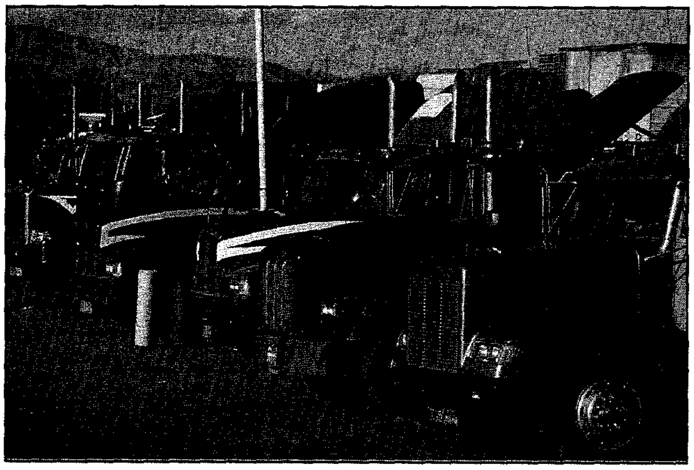
[101] Yrjö, Pilla-Sihvila, *et al.* "Road Weather Service System in Finland and Savings in Driving Costs." *Transportation Research Record No.1387.* Washington, DC: National Academy Press. p. 196–200.

[102] Deeter, D. and Bland, C.E. *Technology in Rural Transportation 'Simple Solutions'.* Federal Highway Administration (FHWA-RD-97-108). October 1997.

[103] "Wisconsin's Winter Weather System." *TR News No. 147.* National Research Council, Washington, DC. March-April 1990. p. 22-23.

4.0 BENEFITS OF ITS FOR COMMERCIAL VEHICLE OPERATIONS

Commercial vehicle operators and the agencies that regulate them will also experience benefits due to implementation of ITS. Improvements in administrative efficiency, avoidance of infrastructure investment, and improvements in highway data collection will improve safety and reduce operating costs. ITS/CVO applications fall into four program areas, as depicted in Figure 4-0. Three of the program areas include ITS applications that enhance communication between motor carriers and the various agencies that regulate them, particularly during interstate freight movements. Applications in the areas of safety assurance, credentials administration, and electronic screening will aid both carriers and agencies in reducing operating expenses through increased efficiency, and assist in ensuring the safety of motor carriers operating on the nation's roadways. The fourth ITS/CVO program area, carrier operations, includes a variety of ITS applications that aid motor carriers in improving their internal operations and provide support for enhancing coordination with regulating agencies. Carriers will move quickly to equip their own fleets with systems that will improve efficiency, safety, or other measures that provide them with a competitive advantage.



ITS / CVO

- → Safety Assurance
- → Credentials Administration
- → Electronic Screening
- → Carrier Operations

Figure 4-0: ITS/CVO Program Areas

4.1 SAFETY ASSURANCE

Improved safety information exchange programs can assist in improving the safe operation of commercial vehicles. By providing inspectors with better access to safety information, the number of unsafe commercial drivers and vehicles removed from the highway can be increased. Onboard monitoring of cargo can alert drivers and carriers of potential unsafe load conditions. Many of these services are beginning to be implemented in the CVO community. Evaluation to date primarily consists of surveys of the opinions of various stakeholders on the expected impacts of the systems. As these services mature, additional benefits data will become available. Data associated with the benefits of safety assurance are classified as shown in Figure 4-1.

Safety Assurance

- → Safety Information Exchange
- → Automated Inspections

Figure 4-1: Taxonomy for Safety Assurance

4.1.1 Summary of Most Recent Evaluations

A nationwide survey of truck and motorcoach drivers assessed their opinions regarding the utility of a variety of ITS applications. Findings regarding safety assurance applications include:[104]

- Truck drivers held much less favorable opinions of Automated Roadside Safety Inspection than motorcoach drivers,
- Truck drivers who carried hazardous materials were very much in favor of Hazardous Materials Incident Response programs, and
- On-Board Safety Monitoring systems were unpopular with both truck and motorcoach drivers; many felt that the technology was too invasive and relied too much on computers.

The Roads and Traffic Authority of New South Wales, Australia, uses a system of remote automated cameras linked to a central processing center to monitor commercial vehicle operations and enforce safety regulations. Cameras are located along interstate highways in New South Wales, along with processors that allow the remote sites to photograph the vehicle, perform vehicle detection and classification and license plate recognition, and forward the information to the central processing site over a communications network. The central site processes the information received to determine average vehicle speeds over highway segments, identify registration infractions or license plate alerts, and determine if there is a need for driver fatigue notification. The central location also issues any necessary citations for recorded infractions. An evaluation of the system, considering the reduction in lives lost and the time lost during unnecessary vehicle stops and inspections, found a benefit/cost ratio of 2.5 to 1.[105]

A cost-benefit analysis of the Commercial Vehicle Information Systems and Network (CVISN) program in Maryland estimated benefit/cost ratios for a variety of ITS/CVO applications.[106] The ratios are based on a 10-year lifecycle for the project, with full deployment of the system in the first year and participation in the program by industry increasing gradually in the early years, more rapidly in the middle years and leveling off in the final years of the lifecycle. Findings include:

- Overall benefit/cost ratios ranging from 3.17 to 4.83,
- Roadside operations of safety enforcement with benefit/cost ratios between 4.01 to 6.08,
- The benefit/cost ratios for state agencies are between 1.41 and 1.66, and
- Commercial motor carriers achieving benefit/cost ratios between 6.49 and 10.71.

104 *Driver Acceptance of Commercial Vehicle Operations (CVO) Technology in the Motor Carrier Environment.* FHWA Report (FHWA-JPO-97-00 10). undated.

105 ITE 1999.

106 *A Report to the Maryland General Assembly Senate Budget and Taxation Committee and House Appropriations Committee regarding Commercial Vehicle Information Systems and Network.* Maryland DOT report to the Maryland General Assembly. November 1998.

A survey of motor carriers operating in the state of Maryland provides additional insight regarding the opinions of the carriers regarding several safety assurance applications. The percentages given for particular responses are determined based on the number of responses to the entire survey rather than each individual question. For most questions, many respondents were unable to respond to the question. Consequently, response rates for particular questions do not sum to 100%.[107]

- Approximately 14% of respondents believed that electronic application for Controlled Hazardous Substances (CHS) permits have little or no value, while almost 5% were neutral. Approximately 12% felt that they would be valuable.
- Regarding the value of online access to fleet safety information and traffic and road conditions, approximately 34% of respondents favored online access to fleet safety information. Another 11% assigned little or no value to it, while roughly 10% were neutral.
- When asked to assess the statement that electronic roadside clearance at mainline speeds will decrease the number of unsafe and illegal carriers, roughly 42% of carriers were neutral, about 32% agreed, and over 25% disagreed.

4.2 CREDENTIALS ADMINISTRATION

Services that support in-house administrative functions can provide savings to state and administrative agencies. Electronic credentialing can improve the time required for states to approve operating permits. Data warehouses can facilitate the exchange of credentials data between agencies and jurisdictions. Credentials administration can be further classified as shown in Figure 4-2.

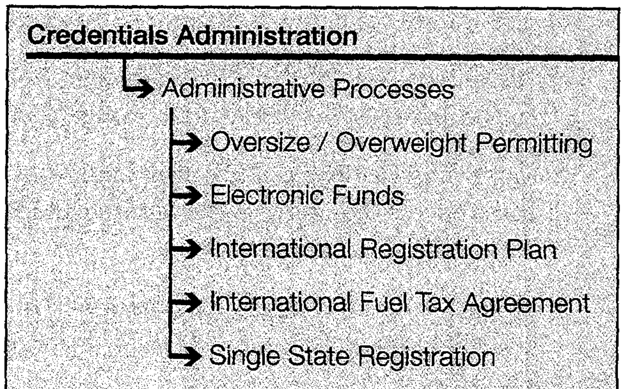


Figure 4-2: Taxonomy for Credentials Administration

4.2.1 Summary of Most Recent Evaluations

The nationwide survey of truck and motorcoach drivers discussed in Section 4.1.1 requested drivers' opinions regarding credential administration applications. Commercial Vehicle Administrative Processes were not favored by truck drivers, with most feeling the service was an invasion of privacy by the government, and some held concerns that the system relied too heavily on computers. Motorcoach operators were very much in favor of these systems, however, feeling that the automated systems could reduce paperwork, make it easier to comply with regulations, and give them an advantage over other drivers.[108]

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[107] Bapna, Sanjay and Zaveri, Jigish. *Perceived Benefits and Utilization of Technology: A Comprehensive Survey of the Maryland Motor Carrier Industry*. ITS America 2000 Annual Meeting. Boston, Massachusetts. 1-4 May 2000.

[108] *Driver Acceptance of Commercial Vehicle Operations (CVO) Technology* undated.

The Maryland analysis of CVISN discussed in the previous section found benefit/cost ratios for credential processing to be between 1.93 and 3.00.[109]

The survey of Maryland motor carriers, also discussed in Section 4.1.1, provides additional insight regarding the opinions of the carriers regarding several ITS applications for administrative processes. The percentages given for particular responses are determined based on the number of responses to the entire survey rather than each individual question. For most questions, many respondents were unable to respond to the question. Consequently, response rates for particular questions do not sum to 100%.[110]

- Respondents were asked to rate the potential value of Electronic Data Interchange (EDI) and the Internet for conducting business with Maryland State Agencies. On a scale of one to three, the potential values of EDI and the Internet were 1.85 and 2.04, respectively, for small carriers. As fleet sizes grow, the potential values of these technologies increase and are approximately the same for both technologies. For fleet sizes of 25 or more, the potential value of these technologies is 2.2, which is relatively high. Current users of EDI and Internet technologies rated the potential value of these technologies higher than non-users.
- More than one-third of the respondents believed that electronic fuel tax application and filing is valuable, while almost 13% were neutral. Roughly 10% felt that it has little or no value.
- Regarding electronic application for Oversize/Overweight (OS/OW) permits, approximately 20% of respondents thought that the service would be valuable. Nearly 7% were neutral and roughly 13% felt this technology has little or no value.
- Roughly 35% of respondents thought that electronic access to Maryland motor carrier regulations was valuable. About 10% were neutral and another 10% believed that the use of this technology has little or no value.
- Regarding the statement that respondents would find it easier to comply with regulations if all agencies support more efficient processing, the majority (60%) agreed with the statement, nearly 29% were neutral, and approximately 11% disagreed.
- Approximately 40% of carriers were impartial to the statement that there is a lack of timely information exchange between themselves and the agencies. Roughly 39% agreed, while another 21% disagreed.
- Nearly 33% of those responding felt electronic registration is valuable, roughly 13% were neutral, and approximately 11% thought it has little or no value.

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109 *A Report to the Maryland General Assembly* 1998.

110 Bapna 2000.

4.3 ELECTRONIC SCREENING

Electronic screening of commercial vehicles can reduce congestion at inspection stations, improve travel time for commercial vehicles, and help operating companies and regulating agencies reduce costs. Allowing safe and legal carriers to bypass weight and safety inspection stations without stopping can reduce congestion at the facilities. Roadside electronic screening allows authorities to investigate a larger portion of potentially unsafe vehicles. Figure 4-3 displays the taxonomy for classifying benefits data related to electronic screening.

4.3.1 Summary of Electronic Screening Impacts

Studies cited in previous ITS Benefits reports estimated the benefits of various electronic screening programs based on their intended operating strategies and statistics on current motor vehicle operations. The Crescent project, investigating the implementation of all types of electronic screening in the states along the West Coast of the U.S., found a benefit/cost ratio of 4.8 to the state agencies for fully implementing the program.[111] Another study found government benefit/cost ratios ranging from 5.4 to 7.9 for automated roadside inspections, electronic clearance and one-stop/no-stop shopping.[112] A simulation study of an advanced truck weigh station permitting transponder equipped vehicles to bypass the scales found significant delay savings for non-equipped vehicles as the number of trucks equipped with transponders increased.[113] These early studies of the potential of electronic screening indicated that the systems could produce significant benefits.

Electronic Screening

- Safety Screening
- Credential Checking
- Border Clearance
- Weight Screening

Figure 4-3: Taxonomy for Electronic Screening

4.3.2 Summary of Most Recent Evaluations

A pilot study referred to as the Intelligent Transportation Border Crossing System (ITBCS) was conducted at the Peace Bridge. The Peace Bridge is a major crossing facility between Buffalo, New York (U.S.A.), and Fort Erie, Ontario (Canada). The ITBCS is a transponder based system that identifies common carriers, autos, etc. that cross the bridge with the intention of speeding the processing of both customs and immigration information. A simulation study indicated that significant benefits would result from a full deployment of the system. On the U.S. side of the bridge, comparing scenarios of 0% and 50% of transponder usage, both trucks and autos received significant timesavings. Trucks saved an average 66% overall in inspection times while the average time for autos in the system decreased 35%. On the Canadian side, time for trucks in the system was reduced 40%.[114]

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111 The Crescent Evaluation Team. *The Crescent Project: An Evaluation of an Element of the HELP Program.* Executive Summary and Appendix A. February 1994.

112 Booz, Allen & Hamilton. *Study of Commercial Vehicle Operations and Institutional Barriers.* Appendix F. McLean, VA: Booz, Allen & Hamilton, November 1994.

113 Glassco, R., *et al. Studies of Potential Intelligent Transportation Systems Benefits Using Traffic Simulation Modeling: Volume 2.* Mitretek Systems Report (MTR 1997-31). McLean, VA: Mitretek Systems, June 1997.

114 Nozick, L., *et al. Evaluation of Advanced Information Technology at the Peace Bridge.* Cornell University & Rensselaer Polytechnic Institute Report. April 1999.

The field operational test involving the Ambassador Bridge Border Crossing System (ABBCS) demonstrated the ability of ITS services to improve safe and legal border crossings between Detroit, Michigan (USA), and Windsor, Ontario (Canada). The system studied for the Ambassador Bridge identified trucks, crews, cargo, and commuter vehicles, processed them quickly and facilitated electronic payment of the bridge toll. A simulation study of the bridge determined the impact of the system when all four traffic lanes on the bridge were open to equipped and non-equipped vehicles. The simulation showed that the time between an equipped truck entering the lane leading to the customs station and the same truck exiting the station could be reduced by 50%. The simulation also showed that as the percentage of equipped trucks increases, the benefits of the system are more pronounced.[115]

The nationwide survey of truck and motorcoach drivers discussed in the preceding two sections[116] found that both motorcoach and truck drivers held favorable opinions of commercial vehicle electronic clearance systems. The survey found a 2:1 ratio of truckers strongly favored this service to those strongly opposing it. A similar ratio for motorcoach drivers was 3:1 in favor of the service.

The survey of motor carriers operating in the state of Maryland, discussed in the preceding section, recorded the following opinions of the carriers regarding electronic screening applications. The percentages given for particular responses are determined based on the number of responses to the entire survey rather than each individual question. For most questions, many respondents were unable to respond to the question. Consequently, response rates for particular questions do not sum to 100%.[117]

- About 29% of respondents believed that electronic roadside clearance is valuable, nearly 10% did not feel it is valuable, and almost 5% were neutral.
- Twenty-four percent of respondents were willing to participate in a weigh/inspection bypass program despite the possibility of incurring more costs. Another 23% were neutral, while the majority, 53%, would not be willing to participate.

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[115] Booz-Allen & Hamilton. *Final Evaluation Report: Ambassador Bridge Border Crossing System (ABBCS) Field Operational Test.* Prepared for ABBCS FOT Partners. May 2000.

[116] *Driver Acceptance of Commercial Vehicle Operations (CVO) Technology* undated.

[117] Bapna 2000.

4.4 CARRIER OPERATIONS

ITS/CVO can improve carrier operations by improving the scheduling of vehicles and reducing the number of empty loads. Administrative compliance costs can be reduced for carriers by participating in automated state credentialing processes. The classification for data related to carrier operations is shown in Figure 4-4.

4.4.1 Summary of Carrier Operations Impacts

Previous reports of the benefits of ITS Carrier Operations services have consisted primarily of anecdotal information from carriers implementing the systems. Carriers report cost savings and productivity gains resulting from enhanced communication with drivers. Those implementing Computer Aided Dispatch (CAD) systems report significant benefits in increased vehicle utilization.[118]

Carrier Operations

- Fleet Management
  - Scheduling
    - Dispatching
    - Routing
  - Vehicle Tracking
    - Automated Vehicle Location
- Traveler Information
- Onboard Monitoring
  - Trip Monitoring
  - Cargo Monitoring
- Electronic Credentialing

Figure 4-4: Taxonomy for Classification of Carrier Operations Benefits

4.4.2 Summary of Most Recent Evaluations

The nationwide survey of truck and motorcoach drivers discussed in the preceding ITS/CVO sections found that truck and motorcoach drivers were in greatest agreement about the usefulness of commercial fleet management systems.[119]

The survey of Maryland motor carriers found that over 36% of respondents felt that having access to information about traffic and road conditions is valuable. About 13% felt it would have little or no value, while another 9% were neutral. The percentages given for particular responses are determined based on the number of responses to the entire survey rather than each individual question. For most questions, many respondents were unable to respond to the question. Consequently, response rates for particular questions do not sum to 100%.[120]

[118] ATA Foundation, Inc. *Survey of the Use of Six Computing and Communications Technologies in Urban Trucking Operations.* Alexandria, VA: American Trucking Association, 1992.

[119] Driver Acceptance of Commercial Vehicle Operations (CVO) Technology undated.

[120] Bapna 2000.

5.0 BENEFITS OF INTELLIGENT VEHICLES

ITS services focusing on the vehicle include those functions that assist the driving task or recommend control actions. Although many in-vehicle services are directly affected by non-vehicle infrastructure systems, for purposes of classification this section considers those systems that directly influence the driving task as part of the Intelligent Vehicle Program Area.

Most Intelligent Vehicle services are applicable across all platforms of vehicles. However, a few services have been developed for specific types of vehicles. For example, unlike other types of vehicles, commercial vehicles may have cargo-monitoring systems to alert drivers of possible load shifting or hazardous materials leakage. Because there have been few reported benefit data for individual platforms, this report classifies all data related to Intelligent Vehicles into driver assistance and collision avoidance and warning systems.

5.1 DRIVER ASSISTANCE

ITS services that assist in the driving task are entering the marketplace. In-vehicle vision enhancement may improve safety for driving conditions involving reduced sight distance due to night driving, inadequate lighting, fog, drifting snow, or other inclement weather conditions affecting visibility. Navigational systems are also included here as they provide assistance to the driver in unfamiliar surroundings. Figure 5-1 summarizes how benefits data are classified under driver assistance.

5.1.1 Summary of Most Recent Evaluations

The INTEGRATION simulation model was used to estimate the safety impact of the TravTek project, which tested in-vehicle navigation devices in Orlando, Florida. The simulation consisted of a representation of the Orlando roadway network, and performance parameters obtained during the field studies. Analyses were performed to estimate the crash risk of motorists using navigation devices compared to motorists without them. In addition, the safety impacts on the entire traffic network (both equipped and unequipped vehicles) were analyzed. Results indicated an overall reduction in crash risk of up to 4% for motorists using navigation devices, due to improved wrong turn performance and the tendency of the navigation system to route travelers to higher-class facilities such as freeways, which typically have lower crash rates. When diversion around incidents or congestion occurred, increased safety risks of up to 10% were estimated for the equipped vehicles, due to diversion to smaller roads that historically have a higher rate of crashes per VMT,

Driver Assistance

- → Vision Enhancement
- → Navigation
  - → Route Guidance
  - → Positioning/Location

Figure 5-1: Taxonomy for Driver Assistance

while the overall network experienced a safety impact ranging from neutral to a slight improvement. The network safety improvements were experienced when diversion from congested roadways reduced the level of congestion for the remaining equipped and non-equipped vehicles and helped to smooth traffic flows on those roads.[121]

TravTek users perceived that their driving was safer. Based on survey data, users felt less nervous and confused and more confident, attentive, and safe, with local users being significantly more positive than renters. Users also felt that the use of TravTek did not interfere with their driving task. While users were no more likely to be involved in close calls than were nonusers, users who were interacting with TravTek immediately before a near-crash were more likely to feel that they had contributed to close calls.[122] In-vehicle navigation devices can benefit users in terms of travel time and route finding. A field operational test suggests system benefits when wider deployment appears. The TravTek test in Orlando found that for unfamiliar drivers, wrong turn probability decreased by about 33% and travel time decreased by 20% relative to using paper maps, while travel planning time decreased by 80%.[123] The TravTek yoked driver study, measuring the travel times of drivers with and without in-vehicle devices, demonstrated that the system reduced traveler's trip-planning time for unfamiliar destinations; however, there were no statistically reliable reductions in travel time from origin to destination for all but one of the origin/destination pairs studied.[124] Simulations using data collected during the TravTek test predicted an increase in throughput. Using constant average trip duration as a surrogate for maintaining level of service, a market penetration of 30% for dynamic route guidance results in the ability to handle 10% additional demand.[125]

The ADVANCE project in the northwest suburbs of Chicago tested the time effects of dynamic route guidance through in-vehicle devices using a yoked vehicle study on an arterial network with limited probe data. The aggregate data set demonstrated that motorists could reduce travel time by 4% under normal or recurring conditions; however, this result was based on a small sample size with a relatively high standard deviation.[126] It did appear that the dynamic route guidance concept, as implemented in ADVANCE, could detect some larger delays and help drivers to avoid them.

Beginning operation in the spring of 1994, the Vehicle Information and Communication System (VICS) is considered to be the forefront of ITS in Japan. In 1998 the system covered four cities: Tokyo, Aichi, Osaka, and Kyoto, and provided drivers with road condition information and alternative route choices to avoid congestion. Drivers using the system reported that they felt less stressed due to the provided advice. They also indicated that they would like the area of service expanded. Road tests of the system have indicated that the dynamic route guidance provided saves about 15% of travel time.[127]

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121 Inman, V., *et al. TravTek Evaluation: Orlando Test Network Study*. Federal Highway Administration Report (FHWA-RD-95-162). Washington, DC: January 1996.

122 Inman, V., *et al. TravTek Evaluation: Rental and Local User Study*. Federal Highway Administration Report (FHWA-RD-96-028). Washington, DC: March 1996.

123 Inman, *et al. Orlando Test Network Study* 1996.

124 Inman, V., *et al. TravTek Evaluation Yoked Driver Study*. Federal Highway Administration Report (FHWA-RD-94-139). Washington, DC: October 1995.

125 Van Aerde, M., and Rakha, H. *TravTek Evaluation: Modeling Study*. Federal Highway Administration Report (FHWA-RD-95-090). Washington, DC: March 1996.

126 Schofer, J. *et al. Formal Evaluation of the Targeted Deployment: Vol. II*, Appendix J. Northwestern University Transportation Center. July 1996.

127 "VICS reduces travel time by 15%." *ERTICO News*. January 1998. p. 10.

5.2 COLLISION AVOIDANCE AND WARNING

Collision avoidance and warning systems are expected to result in both safety benefits and effective capacity benefits by reducing the number of incidents. Collision avoidance includes several user services such as intelligent cruise control, rear-end crash avoidance, and road departure avoidance. Each of these user services may take on three different levels of control. The lowest level warns or suggests to the driver what action to take. The middle level responds to safety-compromising positions by taking limited control of the vehicle. For example, intelligent cruise control could slow a vehicle if approaching a lead vehicle too quickly. The highest level of control would be when the system overrides the driver and takes complete control of the vehicle. Figure 5-2 presents the classification of benefits for collision avoidance and warning.

Collision Avoidance and Warning

- Intelligent Cruise Control
- Rear End
- Road Departure
  - Lane Change / Merge
  - Road Departure
- Intersection
- Longitudinal Control
  - Speed Control
- Low Traction
- Collision Notification
  - Automated
    - Mayday
- On-board Monitoring
  - Driver Condition
  - Vehicle Diagnostics

Figure 5-2: Taxonomy for Collision Avoidance and Warning Benefits

5.2.1 Summary of Most Recent Evaluations

Previous studies of collision avoidance and warning systems estimated the potential impact of these systems on the highway system. A 1997 National Highway Traffic Safety Administration (NHTSA) study estimated the possible effectiveness of several collision avoidance technologies. Estimates for rear-end collision avoidance systems included 42% effectiveness in reducing crashes when the leading vehicle decelerated, 75% effectiveness when the leading vehicle stopped, and 51% effectiveness overall. Lane change or lane merge warning systems were estimated to decrease all lane change collisions by 37%. Road-departure countermeasures were estimated to have an effectiveness of 24%. The study also indicates that the economic benefits of the three systems together would be approximately $25.6 billion (based on the 1994 value of the dollar).[128] Field trials of collision avoidance and warning systems are expanding knowledge of the impacts of these systems.

[128] Kanianthra, Dr. Joseph, and Mertig, A. *Opportunities for Collision Countermeasures Using Intelligent Technologies.* National Highway Traffic Safety Administration. Washington, DC: 1997.

The results of the federally sponsored field operational test (FOT) of adaptive cruise control (ACC) indicate mixed results for this system regarding safety. The study revealed that the interaction between driver and machine in the important safety task of maintaining vehicle headways raises several issues for which the safety impacts are unclear. However, the study did note an increase in the number of participants conforming to the flow of traffic from 29 of 108 without ACC to 42 of 108 with the system operational, a 12% increase. This indicated that adaptive cruise control has potential for promoting a more uniform traffic flow.[129]

An analysis of data collected during the adaptive cruise control field operational test assessed the safety impact of ACC based on situations encountered by the volunteers participating in the field study. Analysis of the number of close calls, defined as near collisions with or without driver intervention or cases of driver error requiring corrective action, determined that adaptive cruise control was associated with a lower rate of close calls per million vehicle kilometers of travel (MVKmT) on freeways. For travel on arterial roadways, adaptive cruise control was associated with an increase in the rate of close calls per MVKmT among a subset of participants who also had a high rate of close calls during manual operation. The study, performed by the Volpe National Transportation Systems Center, also assessed the impact of the adaptive cruise control on a variety of other relevant safety measures.[130]

A study in the south Swedish town of Eslov (population 30,000) equipped the personal vehicles of 25 people with adaptive speed control. The study assessed, through driver interviews, the opinions of participants regarding the system after two months of driving with the system engaged. During the field trial, an active accelerator pedal prevented the vehicles from exceeding the citywide speed limit of 50 km/h, with the system being activated by roadside transponders located on the 10 roadways entering the city. Driver behavior was also assessed through observation while drivers traversed a predetermined test route. Results from driver interviews following the two-month evaluation period indicate that drivers had a positive opinion of the system:

- Seventy-five percent of the drivers consider adaptive speed control more positively than they expected before the trial.
- Three out of four drivers also indicated that they are driving more smoothly and at generally lower speeds while the function is operating.
- More than half of the participants found the driving experience more comfortable with the system engaged.
- A majority of the participants wanted the system to be extended to all speed limits within the urban area, not merely the 50 km/h legal limit.
- A vast majority of the participants prefer adaptive speed control to physical speed countermeasures such as humps, chicanes, and mini-roundabouts.

The observations of driving behavior after the trial period showed an increased tendency of participating drivers to yield when interacting with other drivers and in critical situations at signalized intersections. Given the limited number of vehicles involved, there were no direct benefits to traffic safety during the field trial.[131]

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[129] Fancher, P., *et al. Intelligent Cruise Control Field Operational Test (Final Report).* NHTSA Report (DOT HS 808 849). Washington, DC: May 1998.

[130] U.S. DOT. *Evaluation of the Intelligent Cruise Control System Volume I.* U.S. DOT Report (DOT-VNTSC-NHTSA-98-3). November 1998.

[131] Almqvist, Sverker. "Speed Adaptation: A Field Trial of Driver Acceptance, Behaviour and Safety." 5th World Congress on Intelligent Transport Systems. Seoul, South Korea. 12-16 October 1998.

A German simulation study investigated the safety impact of a collision avoidance system that used longitudinal vehicle control to attempt to prevent crashes. The system uses information gathered by microwave radar and computer vision sensors to control vehicle speed with actuators that allow the control of acceleration and braking. Braking is automatically controlled only to avoid an impending collision if the driver has not yet applied the brakes. Values of simulation parameters were based on the experimental closed test facility and a field trial of the system providing only collision warnings in and around the city of NordHausen, Germany. The study measured the frequency of collisions during numerous simulations of vehicles operating under a variety of scenarios. In each situation, the lead vehicle in a platoon decelerates to simulate an unsafe maneuver.

Reductions in the number of crashes when comparing various levels of market penetration of the collision avoidance system to the base case of no equipped vehicles ranged considerably under the circumstances investigated during the study. The smallest reduction was 9% when the lead vehicle brakes at the maximum rate to a complete stop and 10% of the vehicles in the platoon have collision avoidance systems. The greatest reduction was a 60% reduction in the number of collisions when the lead vehicle brakes at 20% of the maximum rate to a complete stop and 50% of the vehicles in the platoon have collision avoidance systems.[132]

[132] Sala, Gianguido, and Lorenzo Mussone. "The Evaluation of Impact on Traffic Safety of Anti-Collision Assist Applications." 6th World Congress on Intelligent Transport Systems. Toronto, Canada. November 8-12, 1999.

6.0 SUMMARY

The evaluation of implemented systems and emerging concepts of ITS has been an ongoing process. Significant knowledge is available for many ITS services, but many gaps in knowledge also exist. This report has summarized much of the quantifiable data on ITS impacts collected by the JPO. In general, ITS services have shown some positive benefit. Negative benefits are usually outweighed by other positive impacts. For example, higher speeds and improved traffic flow result in increases in nitrous oxides; however, other emission measures, fuel consumption, travel time, and delay are reduced.

Due to the wide range of different technologies used to implement these services and the difference in variables between implementations, in many cases it is difficult to predict the potential impacts of individual ITS services planned for a particular area. Also, ITS services are beginning to be incorporated into the planning process and are included with the addition of traditional capacity or service. When this occurs, it is very difficult to measure the separate impacts of the additional capacity and the individual ITS services. However, through simulation and comparison with similar services that have been implemented elsewhere, planners and decision-makers may be able to estimate the contribution of the ITS services. Furthermore, where measured or predicted data on ITS performance are not available, subjective data or anecdotal benefits may be available. This type of data can be determined through questionnaires, interviews, or case studies.

Although further evaluation of ITS services is an ongoing effort, the remainder of this section summarizes the availability and depth of known data and points to where gaps in the knowledge exist. The number of references represented in the following tables differs from the total number cited in this report. Many reports cover more than one measure of effectiveness for a given deployment or data from several related or unrelated ITS deployments. These references appear more than once in the summary tables. The cost impacts column contains references reporting benefit/cost ratios. The authors acknowledge that other data may exist which could have been included and has yet to be uncovered in their ongoing literature review. Those with appropriate references are encouraged to submit them to the authors via the online database.

Table 6-1 depicts the quantity of reports in the database discussing the performance of applications in each ITS application area by performance measure. Reviewing the table, it is apparent that the level of benefit information in the database reflects the level of deployment of various ITS components. The applications with the greatest number of evaluations are those taking place in metropolitan areas, which have been the focus of many deployment efforts. As the number of statewide and rural ITS deployments increase, the number of related evaluations is also increasing. The relatively large number of Road Weather Management System evaluations indicates the increase in deployment of related ITS applications. The reader interested in finding available benefits information on a particular measure of effectiveness can use this table as a cross-reference into the report and the ITS Benefits Database.

Number of References

0 - ○
1 to 3 - ◔
4 to 6 - ◑
7 to 10 - ◕
>10 - ●

		Safety	Time & Delay	Capacity/Throughput	Cost	Customer Satisfaction	Energy & Environment	Other
Metropolitan	Arterial Management Systems	●	●	◔	◕	◑	◕	○
	Freeway Management	●	●	◑	◑	◑	◑	○
	Transit Management	◑	●	◔	◕	◑	◔	○
	Incident Management	◑	●	◔	●	◑	◑	○
	Emergency Management	◑	◔	○	○	○	○	○
	Electronic Toll Collection	◔	◔	◔	◔	◔	◔	○
	Electronic Fare Payment	○	◔	○	◔	◔	○	◔
	Highway-Rail Intersection	◔	◔	○	○	◔	◔	○
	Regional Mutimodal Travel Information	◑	◑	◔	◔	◕	◑	◔
	Information Management	○	○	○	○	○	○	○
Rural	Traveler Safety and Security	◔	○	○	○	◔	○	○
	Emergency Services	◔	◔	○	◔	○	○	○
	Tourism and Travel Information	○	○	○	○	○	○	○
	Public Transit and Mobility Services	○	○	○	◔	○	○	○
	Infrastructure Operation and Maintenance	◔	◔	○	○	○	○	○
	Road Weather Management	◑	◑	◔	◑	○	○	○
ITS/CVO	Safety Assurance	○	○	○	◑	◔	○	○
	Credentials Administration	○	○	○	◔	◔	○	◔
	Electronic Screening	◔	◔	○	◑	◔	○	○
	Carrier Operations	○	◔	○	◑	◔	◔	◑
I.V.	Driver Assistance	◔	◑	◔	○	◔	○	○
	Platform Specific	○	○	○	○	○	○	○

Table 6-1: Summary of Available Data by Benefit Measure (as of 15 February 2001)

Tables 6-2 through 6-5 present the number of references in the database by ITS service or program area, including more detail on the types of applications discussed within each application area. Again, it is evident that most of the data collected to date are concentrated within the metropolitan areas. This is probably due to the fact that the metropolitan program has been in existence longer and is much more developed than rural or CVO. The heaviest concentrations of data in the metropolitan area are in arterial management systems, freeway management, incident management, and regional multimodal traveler information. Most of the available data on traffic signal control systems discuss adaptive traffic signal control. For freeway management, most data reflect benefits related to ramp metering. There are also few data for highway-rail intersections compared to no data available in the 1999 report.

Currently, not enough benefits data have been collected regarding rural ITS to develop any general conclusions. However, this area of ITS has seen a significant growth in reported benefits since the 1999 Benefits Report. Several state and national parks are now examining, testing, and implementing technologies to better transmit tourism and travel information. Also, several rural areas are implementing public transit services. Furthermore, states are now beginning to incorporate ITS into the operation and maintenance of facilities and equipment. Much of the data reported for rural ITS are concentrated in the areas of crash prevention and security. Also, a significant amount of information is available for road weather management activities.

Components	Data Available
Arterial Management Systems	**49**
Traffic Surveillance	2
Traffic Control	38
Information Dissemination	0
Public Safety / Enforcement	9
General	0
Freeway Management Systems	**29**
Traffic Surveillance	3
Traffic Control	10
Information Dissemination	13
Public Safety	3
General	2
Transit Management Systems	**16**
Personal Rapid Transit	1
Transit Management & Operations	11
Security	1
Transit Information	3
General	1
Incident Management Systems	**25**
Surveillance	3
Detection	5
Response	15
Clearance	1
General	1
Emergency Management	**5**
Emergency Management	5
Emergency Vehicle	0
General	0
Electronic Toll Collection	**10**
Toll Administration	2
Toll Collection	5
Toll Vehicle	3
General	0
Electronic Fare Payment	**5**
Administration/Management	4
Transit Vehicle	1
General	0
Highway-Rail Intersection	**6**
Surveillance	1
Control	1
Display - Audio/Visual	3
Public Safety	1
General	0
Regional Multimodal Information	**21**
Pre-trip Information	11
En-route Information	10
General	2
Information Management	**0**
Data Archiving	0
General	0
Other Metropolitan Systems	**4**
Travel and Tourism	1
Road Weather Management	2
Operations and Maintenance	1
Parking Management	0

Table 6-2: Number of Metropolitan ITS References in the Database (as of 15 February 2001)

Components	Data Available
Crash Prevention and Security	**7**
Surveillance/Monitoring	2
Information Dissemination	5
General	0
Emergency Services	**3**
Detection	2
Mobilization & Response	1
Information Dissemination	0
General	0
Travel and Tourism	**1**
Travel Information	0
Revenue Collection	0
General	1
Traffic Management	**0**
Surveillance	0
Traffic Control	0
Information Dissemination	0
General	0
Transit and Mobility	**3**
Transit Management	0
Traveler Information	0
Electronic Payment	0
Paratransit	3
Ride Sharing and Matching	0
General	0
Operations and Maintenance	**5**
Fleet Management	0
Infrastructure Management	0
Weather Maintenance	4
Work Zone Management	1
Information Dissemination	0
General	0
Road Weather Management	**9**
Surveillance and Monitoring	5
Information Dissemination	4
General	0

Table 6-3: Number of Rural ITS References in the Database (as of 15 February 2001)

ITS/CVO continues to provide benefits to both carriers and state agencies. Although it appears that few data have been collected for ITS/CVO, the data that have been reported are from measures that are often directly measurable. Therefore, it might be expected that these data are accurate and few data points would be necessary to convince carriers, states, and local authorities of the possible benefits of implementing these user services. Also, it may be that few data points are needed to convince local jurisdictions that data sharing and other integration measures between other jurisdictions could provide for significant cost savings and improved service. To date, the largest percentage of benefit data related to ITS/CVO is from carrier operations and electronic screening.

ITS program areas and user services associated with driver assistance and specific vehicle classes are still being developed and planned. Although a few of these services are available in the marketplace, much of the data currently associated with these services are predicted or projected based on how systems are expected to perform. As market penetrations increase and improved systems are developed, there will be ample opportunity to measure and report data based on actual measurements.

Metropolitan integration continues to be an important topic among ITS professionals. Table 6-6 presents the number of entries in the database evaluating systems involving integration of more than one ITS application. The table contains pairs of icons representing the integration links introduced in Figure 2-1 in Section 2. The arrows between the icons represent the flow of information between the applications, while the entries in the second column specify the type of information transferred or the action taken based on the communication. For example, the second entry in the table indicates that two reports within the Benefits Database discuss ITS implementations that include the communication of information on arterial traffic conditions from an arterial management system to a freeway management system.

In reporting integration benefits, it is often difficult to separate the benefits of one component with regard to the other. For example, the benefits achieved by emergency management may not be possible without a well-developed incident management program. Reported data may not indicate these relationships very clearly. The reader is also advised that no attempt is made to attribute the relative impact of the integration on the benefits reported in the database entries; the entries in Table 6-6 indicate only that integration was present in the system evaluated in each of the studies.

Based on the data available, integrated ITS deployments linked with regional multimodal traveler information are most often evaluated. There is also a significant amount of data available for the integration of arterial management with transit management and for freeway and incident management systems. The lack of evaluation reports for many of the integrated systems represented in the table and the scarcity of attempts to specifically identify the benefits made possible through integration indicate a need for further research into the impacts of integration among ITS applications.

ITS applications are reaching ever increasing levels of deployment in the U.S. and worldwide. As experience with additional applications increases, additional benefits will become apparent. Implementing agencies will also learn valuable lessons regarding appropriate implementation and operational strategies. The ITS Joint Program Office will continue to make this information available via the ITS Benefits Database, the Electronic Document Library, and other publications.

Components	Data Available
Safety Assurance	**5**
Safety Information Exchange	2
Automated Inspections	2
General	1
Credentials Administration	**2**
Administrative Processes	2
Electronic Screening	**7**
Safety Screening	1
Credential Checking	2
Border Clearance	2
Weight Screening	1
General	1
Carrier Operations	**9**
Fleet Management	6
Traveler Information	1
On-board Monitoring	0
Electronic Credentialing	2
General	0

Table 6-4: Number of ITS/CVO References in the Database (as of 15 February 2001)

Components	Data Available
Collision Avoidance and Warning	**8**
Intelligent Cruise Control	1
Rear End	2
Road Departure	2
Intersection	0
Longitudinal Control	1
Low Traction	0
Collision Notification	1
On-board Monitoring	1
General	0
Other Driver Assistance	**6**
Vision Enhancement	0
Navigation	6
General	0

Table 6-5: Number of Intelligent Vehicle References in the Database (as of 15 February 2001)

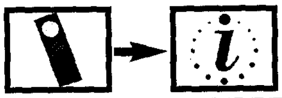
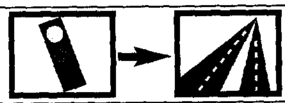
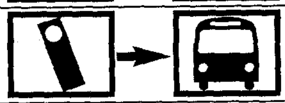
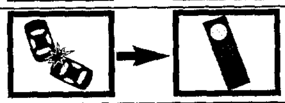
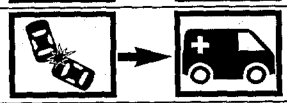
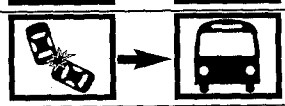
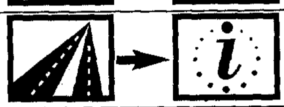
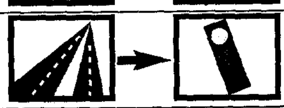
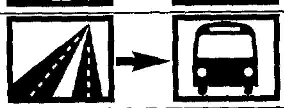
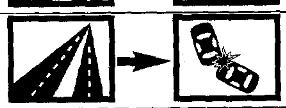
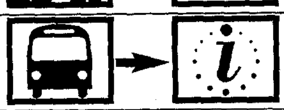
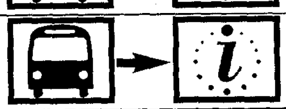
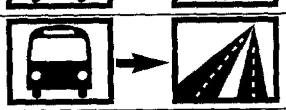
Metropolitan Integration Link	Link Purpose	Data Available
	Affect Travel Decisions	2
	Adjust Ramp Signals or Inform Drivers	2
	Adjust Schedules/Routes	1
	Adjust Response	1
	Affect Traffic Control Strategy	2
	Affect Travel Decisions	11
	Adjust Emergency Response	3
	Affect Control Strategy	4
	Adjust Schedules/Routes	0
	Affect Travel Decisions	8
	Adjust Arterial Signals	1
	Adjust Routes/Schedules	0
	Detect Incidents and Adjust Response	5
	Static Route/Schedule Information	6
	Real-Time Route/Schedule Information	1
	Ramp Signal Priority	0
	Travel Speed Information	0

Table 6-6: Number of Metropolitan Integration References in the Database (as of 15 February 2001)

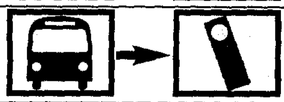
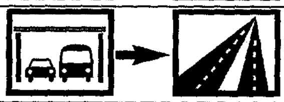
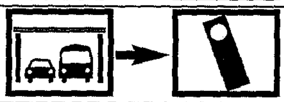
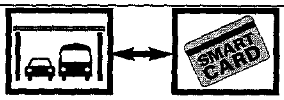
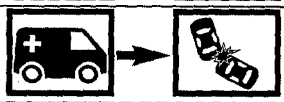
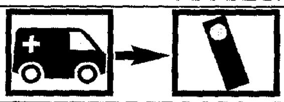
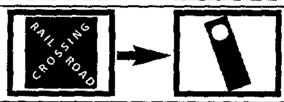
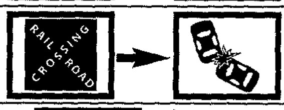
Metropolitan Integration Link	Link Purpose	Data Available
	Signal Priority	8
	Travel Speed Information	1
	Probe Vehicle Information to Affect Control Strategy	0
	Probe Vehicle Times Affect Timing	0
	Share Common Fare Media	0
	Transit Service Planning	0
	Information on Incident Severity, Location, and Type	0
	Information on Incident Clearance	0
	Signal Priority/Preemption	2
	Signal Coordination	0
	Alert	0
	Agencies Participating	0
	Coordinate Timing Across Jurisdictions	3
	Transit Operators with Common Fare Media	1
	Toll Operators with Common Tags	0
	Information on Incident Severity, Location, and Type	0
	Agencies Share Freeway Condition Information	0

Table 6-6: Number of Metropolitan Integration References in the Database (as of 15 February 2001)

APPENDIX 1: REFERENCE LIST

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APPENDIX 2: LIST OF ACRONYMS

LIST OF ACRONYMS

ABBCS	Ambassador Bridge Border Crossing System
ACC	Adaptive Cruise Control
ADIE	Aggressive Driver Imaging and Enforcement
ADMS	Archived Data Management System
ADOT	Arizona Department of Transportation
ADUS	Archived Data User Service
AMWS	Automated Motorist Warning System
APTS	Advanced Public Transportation Systems
ARTIMIS	Advanced Regional Traffic Interactive Management and Information Systems
ATIS	Advanced Traveler Information System
AVI	Automatic Vehicle Identification
AVL	Automated Vehicle Location
B/C	Benefit/Cost
CAD	Computer Aided Dispatch
CCS	Collision Countermeasure System
CCTV	Closed Circuit Television
CHS	Controlled Hazardous Substances
CO	Carbon Monoxide
CVISN	Commercial Vehicle Information Systems and Network
CVO	Commercial Vehicle Operations
DMS	Dynamic Message Signs
DOT	Department of Transportation
EDI	Electronic Data Interchange
E-PASS	Express Pass
ESS	Environmental Sensor Stations
ETC	Electronic Toll Collection
ETTM	Electronic Toll and Traffic Management
FHWA	Federal Highway Administration
FOT	Field Operational Test
FY	Fiscal Year
HAR	Highway Advisory Radio

HC	Hydrocarbon
HRI	Highway-Rail Intersections
IFTA	International Fuel Tax Agreement
IRP	International Registration Plan
ITBCS	Intelligent Transportation Border Crossing System
ITS	Intelligent Transportation Systems
ITS/CVO	ITS for Commercial Vehicles
IVN	In-Vehicle Navigation
IVS	In-Vehicle Signing
JPO	Joint Program Office
LRT	Light Rail Transit
MMDI	Metropolitan Model Deployment Initiative
Mn/DOT	Minnesota Department of Transportation
MVKmT	Million Vehicle-Kilometers of Travel
NHTSA	National Highway Traffic Safety Administration
NO_x	Nitrous Oxide
OOCEA	Orlando-Orange County Expressway Authority
OS/OW	Oversize/Overweight
PC	Personal Computer
PDA	Personal Digital Assistant
PTA	Personal Travel Assistant
PuSHMe	Puget Sound Help Me (Mayday System)
RESCU	Remote Emergency Satellite Cellular Unit
RWIS	Road Weather Information System
SCOOT	Split Cycle Offset Optimization Techniques
SSR	Single State Registration
SWIFT	Seattle Wide-area Information for Travelers
TEA-21	Transportation Equity Act for the 21st Century
U.S. DOT	United States Department of Transportation
VICS	Vehicle Information and Communication System
VMT	Vehicle-Miles of Travel
WISA	Weather-related Intelligent Speed Adaptation System
WSDOT	Washington State Department of Transportation

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